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SOIL SAMPLING TECHNIQUE IN ORCHARDS[1]

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One of the most important steps in nutritional studies of the soil is the sampling of the soil in the field. The best method of sampling in any particular case obviously depends on the purpose of the sampling and on the type of crop involved. The procedures that have been developed for sampling soil in field crops and in pasture crops do not necessarily apply in orchards. Fruit trees have different nutritional requirements; their roots are longer and explore the soil to a greater depth; the plants are perennial; and fertilizers are often applied around the individual plants rather than being spread broadcast. Special consideration, therefore, must be given to the procedure of soil sampling in orchards. Among the factors affecting this procedure, those that need special study include depth of sampling, season of sampling, position with respect to the individual trees, and number of samples in each composite. The investigations reported in this paper were undertaken in an attempt to gain information with respect to these factors.

PROCEDURE

Where there were no stones present in the soil, sampling was done with an auger. Where stones were present, a hole was dug to the required depth with a shovel, and a slice was taken up the side of the hole with an open tin can. Equal amounts of soil were selected from each location, and were well mixed. The soil was then screened through a $\frac{1}{4}$-inch mesh sieve while still moist, and was allowed to air-dry.

For nutrient determinations, the soil was extracted with a 2 : 1 ratio of water : soil. Carbon dioxide was bubbled through the mixture, which was stirred every 15 minutes. At the end of two hours, it was filtered. The filtrate was analysed for P, K and Ca. Phosphate was determined by the use of ammonium molybdate and aminonaphtholsulfonic acid, K by the use of sodium cobaltinitrite, and Ca by the use of oleic and stearic acids. The procedures used will be described in greater detail in a subsequent publication. All determinations were made with a Klett-Summerson colorimeter. The methods used for pH, electrical conductivity and organic matter have been described in previous papers (14, 15) by the author.

The orchards used as a basis for these studies were all situated in the Okanagan Valley in British Columbia. They were all irrigated by the furrow method. A wide variety of cover crops was grown from orchard to orchard, but in no case was the orchard clean cultivated. The method

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commonly used in applying fertilizers was to scatter them by hand in a wide band within the outer spread of the limbs. This was done in either the late fall or early spring.

DEPTH OF SAMPLING

In most agricultural areas, the three major elements (N, P, K) are found in available form in greater abundance in the surface soil than in a similar volume of the subsoil. For this reason more than any other, the recommendation for soil sampling has usually been to take the samples from the top 6 or 7 inches only. In many cases, this procedure has been applied equally to orchards and to field crops. There appears to be a growing feeling, however, that with deep-rooted crops an analysis of the surface soil only is not sufficient. Lohse and Ruhnke (9) found in Ontario that the P status of a soil could not be adequately described from surface samples only. Reuther (10) in New York sampled orchard soils to a depth of 36 inches, for K analyses. Lilleland and Brown (8) in California sampled orchard soils to a depth of 48 inches. Stephenson and Schuster (12) in Oregon studied the nutrient contents of nut orchard soils to a depth of 10 feet. Baker (1) in Indiana sampled orchard soils at depths of 0-8, 8-16, and 16-24 inches.

If the subsoil is to be sampled as well as the surface soil, the question arises as to whether it should be done at certain standard depths or by soil horizons. In soil survey work, it should obviously be done by horizons. In routine studies of nutrient status, however, this would be much too laborious. It would be necessary to dig a large enough pit at each location to study the profile before samples were taken for analysis.

As a guide in determining suitable standard depths for sampling, studies have been made of the depth of rooting of apple trees. These studies have already been reported (16). A great deal of variability in concentration of roots at each soil depth was encountered. Among the factors affecting the concentration at any one depth were the soil texture, the type of profile, the cultural treatment, and the age of the trees. In general, however, four divisions by depth of the soil were indicated: (1) 0-8 inches, containing a high concentration of cover crop roots and usually a relatively low concentration of tree roots; (2) 8-24 inches, usually containing the greatest concentration of tree roots; (3) 24-60 inches, containing a lesser concentration of tree roots; (4) over 60 inches, usually containing only a few scattered roots.

On the basis of the above divisions, samples were taken in 1940 from 75 plots of McIntosh trees, at depths of 0-8, 8-24, and 24-60 inches. The method of collecting the samples has already been described (14). It is not proposed at this time to present in full the results of the chemical analyses; however, some of the findings with respect to soil depth are pertinent to this discussion.

In Table 1 are listed data on samples selected to illustrate certain points. The first four plots are a series of fertilizer plots in the Penticton district, the next two are from a series of fertilizer plots in the Kelowna district, and the last four are from grower-owned and grower-treated orchards. In some cases the soil was underlaid by a mixture of coarse

TABLE 1.—SOME EFFECTS OF DEPTH ON NUTRIENT CONTENT

Plot No.	Soil texture	Treat-ment	Depth	P	K	Ca	pH	Lime
			inches	p.p.m.	p.p.m.	p.p.m.		%
P1	Silt (eroded)	Check	0-8	0.84	69	485	7.61	1.4
			8-24	0.22	48	559	8.19	5.2
			24-60	0.18	49	469	8.29	2.8
P2	Silt	N	0-8	3.32	105	187	6.85	0
			8-24	1.18	57	455	7.88	2.1
			24-60	0.39	51	484	8.08	5.2
P3	Silt	N-P	0-8	11.91	81	183	6.28	0
			8-24	1.08	51	447	7.47	0.1
			24-60	0.61	46	565	8.13	3.9
P4	Silt	N-P-K	0-8	9.74	132	145	6.36	0
			8-24	1.24	56	542	7.75	0.6
			24-60	0.27	52	590	8.13	5.4
K46	Sandy loam	N	0-8	1.65	80	94	6.27	0
			8-24	0.15	14	20	6.51	0
K51	Sandy loam	N-P	0-8	8.39	80	96	5.67	0
			8-24	0.49	25	29	6.15	0
T2	Sandy loam	N-P-K	0-8	4.00	162	354	6.11	0
			8-24	0.64	78	473	8.06	3.3
K53	Loamy sand		0-8	0.58	57	81	6.04	0
			8-24	0.11	30	21	5.98	0
K16	Sandy loam		0-8	3.06	114	115	6.70	0
			8-24	0.83	56	142	6.96	0
			24-60	0.65	50	381	7.98	3.0
W4	Loamy sand		0-8	2.67	84	71	6.13	0
			8-24	0.52	47	57	6.62	0
			24-60	0.60	40	40	6.95	0

sand and gravel at or above a depth of 24 inches, and so samples were not taken below this depth. Tree yields and other data from these plots have already been reported (13, 14, 17).

Plot P2 is typical of the deep silt soils in the Okanagan Valley. The surface soil is somewhat acid, and the subsoil is alkaline and contains free lime. Both P and K are higher in the surface soil, while Ca is higher in the subsoil. Plot P1 has had the original surface soil removed by erosion. In order to secure adequate information, it is necessary in such cases to take subsoil samples as well as surface samples. Unfortunately, cases of erosion are frequently encountered.

Plot P3 has been treated with P, and Plot P4 with P and K. These treatments are reflected in the analyses of the surface 8 inches, but not in the soil below that depth.

In contrast with the above series of plots are Plots K46 and K51. In this case the soil is sandy, and applications of P fertilizer have enriched not only the surface 8 inches of soil but the subsoil as well.

An analysis of the surface soil only does not enable the operator to classify the pH and lime status of the profile as a whole. In both Plots T2 and K53, for example, conclusions based on the surface soils only would be that lime should be applied, especially if leguminous cover crops are to be grown. An examination of the subsoil, however, shows that while this might hold true with Plot K53, it certainly does not hold true with Plot T2. In Plot K16, no free lime was recorded in the top 24 inches, and in Plot W4 none was recorded in the top 60 inches.

In classifying a soil with respect to its sufficiency of P, K, or Ca, not only is the content of available nutrient important, but so also is the depth of the soil. Many orchards in the Okanagan Valley are planted on shallow soils, underlaid by stones, gravel and coarse sand of little nutritional value. It is obvious that conclusions based on an examination of the surface soil only can be entirely erroneous; for example, compare Plots P1 and K46. The surface soil of K46 contained more available P than did that of P1, but the P content of the leaves was in the reverse order.

Under the soil conditions encountered in Okanagan Valley orchards, it does not appear that sampling of the surface soil only can be considered sufficient. Just how much of the subsoil needs to be sampled, however, is difficult to determine. It will depend on the depth of the subsoil and on the specific purpose of the sampling. The procedure used here at present for nutritional work is as follows:

(1) In research studies, take samples to at least 60 inches, unless coarse gravel or stones are encountered above that depth. In any case, take samples to at least 24 inches.

(2) In routine nutrient deficiency tests, take samples to 24 inches, whether gravel is encountered above that depth or not. If gravel is not encountered above 24 inches, test with an auger or a wire prod to determine the depth of good soil.

SEASON OF SAMPLING

Previous work by a large number of writers has shown that the contents of nitrate N and ammonium N in the soil vary a great deal during the year. This holds true in orchards as elsewhere (1, 2, 5, 7, 11). In special studies of the N status, therefore, frequent sampling is necessary. Even with routine tests of the N status, more than one date of sampling appears advisable. The best dates of sampling will of course depend on climatic factors, crops concerned, moisture conditions, and cultural treatment. The nitrogen problem in irrigated orchards subjected to a wide variety of cover crops and cultural treatments is difficult of solution. This problem is now being studied in the Okanagan Valley. Present indications are that the fruit tree is a better indicator of the nitrogen requirement of the soil than is the soil itself. Until further data are available no definite suggestions can be offered with respect to dates of sampling for N determination.

Seasonal variability does not seem to be as great with P and K as it is with N. In raspberry plantations in British Columbia, Harris and Woods (6) found some seasonal variation in content of available P, but no definite seasonal trends. Available K was low early in the spring, high in May, low in July, somewhat higher in September, and low during the

dormant season. Available Ca was low in March, high in May, then gradually lowered again until the following spring. Mg was similar to Ca, and S was similar to P. In all cases, the seasonal variability was much less than with nitrate. In Quebec, DeLong, Sutherland and Archer (4) reported only comparatively small variations in content of available P during the growing season.

In an attempt to determine the seasonal variation that normally occurs in Okanagan orchards, soil samples were taken in 1945 at monthly intervals from April 5 to December 5. One apple tree was selected in each of eight cover crop plots at the Experimental Substation at Kelowna, and samples were selected from four locations around each of these trees. On April 5, four spots were located at eight feet from the trunk, and composite samples were taken with an auger at depths of 0-8 inches and 8-24 inches. At subsequent sampling dates, samples were taken as close to the original sample as feasible.

The results are summarized in Table 2. Trees receiving similar treatment have been grouped together. As can be seen from this table, complete data were not obtained on the November samples.

TABLE 2.—SEASONAL VARIATION OF NUTRIENTS IN ORCHARD SOIL

Treatment	Month	pH		P		K		Ca	
		0-8 inches	8-24 inches	0-8 inches	8-24 inches	0-8 inches	8-24 inches	0-8 inches	8-24 inches
				p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.
GUNK* (3 trees**)	April	6.32	6.31	0.96	0.31	100	65	72	58
	May	6.17	6.34	1.12	0.30	108	80	76	60
	June	6.23	6.30	1.60	0.30	97	65	84	55
	July	6.21	6.39	0.91	0.32	83	60	59	39
	Aug.	6.16	6.44	0.92	0.40	78	60	66	49
	Sept.	6.27	6.44	0.85	0.30	91	58	68	47
	Oct.	6.30	6.42	0.75	0.37	89	61	69	39
	Nov.	6.35	6.51	—	—	—	—	—	—
	Dec.	6.17	6.26	0.96	0.50	104	69	74	49
GUN (3 trees)	April	6.67	6.58	1.56	0.46	60	19	94	62
	May	6.66	6.61	1.98	0.37	61	17	95	60
	June	6.61	6.61	1.42	0.47	56	14	93	60
	July	6.58	6.56	0.98	0.29	51	15	94	61
	Aug.	6.62	6.54	1.58	0.39	53	18	90	55
	Sept.	6.65	6.55	1.30	0.48	51	15	84	53
	Oct.	6.72	6.61	1.31	0.45	56	14	86	57
	Nov.	6.68	6.67	—	—	—	—	—	—
	Dec.	6.57	6.45	1.91	0.61	56	18	106	79
LUNP (2 trees)	April	6.59	6.55	3.37	0.37	75	20	103	64
	May	6.52	6.61	3.65	0.34	78	23	96	60
	June	6.50	6.51	4.19	0.42	74	22	91	69
	July	6.51	6.46	2.92	0.36	68	24	92	86
	Aug.	6.46	6.54	3.82	0.47	64	22	94	69
	Sept.	6.49	6.62	3.79	0.43	74	20	88	60
	Oct.	6.52	6.65	4.85	0.40	85	21	91	65
	Nov.	6.69	6.68	—	—	—	—	—	—
	Dec.	6.60	6.61	4.96	0.73	91	35	91	79

* G—grass sod, L—ladino clover, U—uncultivated, N—nitrogen, P—phosphate, K—potash.
** Composites of 4 were taken at each tree, so grouping 3 trees means averaging 12 soil samples.

No consistent seasonal trends were found in any of the four soil characteristics measured. If such trends were present, they were masked by errors in sampling. The only conclusion that can be reached from these tests is that, under the conditions of this investigation, there is no definite indication that any one date is preferable for sampling the soil for determination of pH, P, K and Ca. This conclusion would not necessarily apply to other crops, or even to tree fruit soils treated in a manner different from that at the Substation at Kelowna.

POSITION WITH RESPECT TO TREES

It cannot be assumed that sampling of soil in an orchard should be conducted in the same manner as sampling in a field of grain, sugar beets, or pasture. For the most part, orchard soils are quite variable. This is especially true in the Okanagan Valley. Furthermore, the large size and perennial nature of fruit trees tend to induce soil differences at different positions in relation to each tree.

When an orchard soil is sampled for nutritional studies, the question arises as to whether the whole orchard should be sampled as a unit, or whether the samples should be related to a small group of trees. Lilleland and Brown (8) in California state that "A large variation may exist within small areas of apparently uniform soil. A soil analysis cannot, therefore, be safely related to a tree condition unless the sample is taken in close proximity of the tree." Here in the Okanagan Valley, where soil variability is so great, this principle also holds true. It has therefore become customary to take composite samples representing a small plot or a small group of trees only. In some cases, sampling is restricted to the area around one selected tree in what looks like typical soil for the plot or for the orchard (14).

It has become customary to select samples from under the spread of the limbs only (1, 14). This is a practice that is open to question, and one that deserves considerable investigation. Various factors affect the nutrient status of the soil under the limbs as compared with between the trees. Among the more important of these factors are the following:

1. **Application of fertilizers.** In the Okanagan Valley, most growers apply their fertilizers well within the outer spread of the limbs.

2. **Spray materials.** These drip from the leaves of the trees, and become more concentrated under the tree than elsewhere.

3. **Dropping of leaves.** The soil under the tree is usually enriched more by the tree leaves than is the soil elsewhere.

4. **Cover crop.** This may or may not grow in different degree in the centres of the panels as compared with under the trees. In older orchards in the Okanagan Valley, there is usually much more cover crop growing in the centres of the panels than under the trees. The effect of such a condition on the nutrient status of the soil will no doubt depend on how the cover crop is handled.

5. **Use of nutrients.** It is reasonable to suppose that the tree will use nutrients from the soil more rapidly near the tree than farther out. Two factors enter into this situation. In the first place, the feeding roots

of the trees are more concentrated closer to the trunk of the tree (16); and in the second place, the tree roots have been feeding on the soil for a longer period of time closer to the tree.

It would be difficult to forecast just what the combined effects of the above factors would be in any one case. The question arises as to whether the differences from point to point are likely to be great enough to necessitate taking them into consideration in the sampling. In order to determine this, two tests were made in 1943, one in an apple orchard at the Experimental Station at Summerland (Test A), the other in an apple orchard at the Experimental Substation at Kelowna (Test B). The two situations involved may be described as follows:

Test A. Rome Beauty trees, 27 years old, planted 30 × 30 feet apart on the square. Soil a sandy loam, 24 to 36 inches deep, underlaid by gravel. For some years, N + P fertilizers had been applied, although the P fertilizer was discontinued prior to this test. Fertilizers had been applied in a band 4 feet or more in width under the spread of the limbs. Irrigation was by the furrow method and the cover crop was a permanent grass sod. It had not been cultivated for several years.

Test B. Delicious trees, about 25 years old, 30 × 30 feet apart on the square. Soil a light sandy loam, 18 to 24 inches deep, underlaid by gravel. For some years, N + K fertilizers had been applied, although the K fertilizer had been discontinued at the time of this test. Fertilizing, irrigation, and cover crop were similar to those in *Test A*, but cultivation had been somewhat more frequent.

In each test, a row of 4 healthy trees was selected. A point was selected 7 feet from the trunk of each tree. The direction from the trunks of the trees was varied, so that the four points thus selected represented the four points of the compass. A composite was made from the four 0-8 inch samples and one from the four 8-24 inch samples. Three further sets of composite samples were then taken by the same procedure, at the 7-foot distance. In no instance were two borings made in the same direction from any one trunk. Three similar sets of composites were then made at 15 feet from the trunks in *Test A*, and two sets in *Test B*. Finally, two sets were made at 21 feet from the trunks. The 15-foot distance represented the midway points between trees in the same row, and the 21-foot distance represented the centres of the tree squares.

The results are summarized in Table 3. There was considerable variability in the data at any one distance from the trunk. However, it can also be seen that as the distance from the trunk increased, there was a general tendency for the pH to increase, and for the electrical conductivity, P content and K content to decrease. These trends are more apparent in the surface soil than in the subsoil. In *Test A*, the Ca content increased with greater distance from the trunk, and in *Test B* it decreased. The organic matter content was unaffected.

These results can be explained in part by the fertilizer applications. Where P fertilizer had been applied under the spread of the limbs (*Test A*), it would be expected that there would be a marked gradient in P content. The same should hold true of the Ca content, since the P fertilizers contained Ca. Where K fertilizer had been applied, likewise (*Test B*), there should

TABLE 3.—EFFECTS OF SAMPLING AT DIFFERENT DISTANCES FROM TRUNKS OF TREES

Location*	Distance from tree	pH		Conductivity†		P		K		Ca		Organic matter	
		0-8	8-24	0-8	8-24	0-8	8-24	0-8	8-24	0-8	8-24	0-8	8-24
	feet					p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.	%	%
Test A, Summerland													
1	7	5.15	7.53	156	73	10.7	1.2	99	20	302	125	2.3	1.1
2	7	5.46	7.38	218	129	9.1	0.7	152	32	395	114	2.1	1.3
3	7	5.27	7.38	119	106	9.8	3.6	102	22	181	134	2.1	1.1
4	7	5.62	7.39	177	86	10.5	0.8	117	29	351	156	2.3	1.2
5	15	5.69	7.73	85	62	7.6	0.6	71	17	141	209	2.0	0.8
6	15	6.06	7.66	67	71	7.1	0.1	98	19	153	56	2.0	1.1
7	15	6.36	7.54	84	126	7.8	0.1	115	16	160	116	2.3	0.7
8	21	6.74	7.63	42	46	3.3	0.1	75	22	124	66	2.2	1.2
9	21	6.28	7.59	63	49	4.0	0.1	82	19	146	65	2.1	1.0
Test B, Kelowna													
10	7	6.44	6.41	41	26	3.3	0.9	256	140	37	33	1.9	0.7
11	7	6.47	6.49	51	30	3.6	0.5	264	148	43	31	1.8	0.5
12	7	6.18	6.29	44	39	1.8	0.4	200	136	41	27	1.5	0.5
13	7	6.45	6.38	49	30	1.8	0.7	218	156	44	41	1.6	0.3
14	15	6.42	6.48	28	18	0.8	0.2	73	26	83	55	1.4	0.7
15	15	6.29	6.35	27	20	0.8	0.2	72	24	68	68	1.3	0.6
16	21	6.50	6.73	32	29	1.8	0.2	85	22	104	95	1.8	0.9
17	21	6.56	6.68	36	20	1.2	0.1	65	23	102	84	1.8	0.9

* Each "location" was really a set of four locations, from which a composite sample was obtained for each depth.
† The electrical conductivity is expressed in terms of mhos $\times 10^5$.

be a marked gradient in K content. And where sulphate of ammonia had been applied (both tests), the pH would be lowered and the electrical conductivity increased beneath the limbs of the trees.

Some features of Table 3 are difficult to explain. These are the decrease in P and K content with greater distance from the trunk, where P and K fertilizers had not been applied; also the marked increase in Ca content with greater distance from the trunk in *Test B*. It is quite possible that the heavy applications of K fertilizer that had been made closer to the trees in *Test B* had induced heavy leaching of the available Ca into the deeper subsoil.

Whatever the causes of the nutrient gradients indicated in Table 3, the fact remains that such gradients do exist. Indeed, they are great enough to justify taking them into account in sampling the soil.

It may be argued that there is a greater concentration of feeding roots under the limbs than farther out, and that therefore the soil under the limbs is the only soil that requires consideration in nutrient studies. This argument is only partly valid. It does not apply in full to either young trees or to mature trees. With young trees, the roots are constantly reaching out into new soil, and the composition of this soil is therefore just as important as is that of the soil closer to the trees. With mature trees, the roots will already have met in the centres of the panels. The feeding roots may not be as concentrated per unit area in the centres of the panels, but the area represented is in many cases greater than the area of fertilizer application. In any case, it appears obvious that in sampling the soil, the total soil area around each tree should be taken into consideration.

The best method of soil sampling to overcome this difficulty has not been determined. Some systematic procedure of sampling according to the area involved would perhaps prove suitable. The procedure tentatively adopted at the Experimental Station at Summerland is to sample at selected locations in the ratio of 2 : 1 : 1 as follows: two locations under the limbs, usually 6 to 7 feet from the trunk; one location midway between two trees in the row; and one location in the centre of a tree square. On this basis, composites are usually made up from individual samples in multiples of 4.

NUMBER OF SAMPLES IN EACH COMPOSITE

After an extensive investigation of the field sampling of soil, Cline (3) states as follows: "Twenty sampling units of the plowed layer, or ten of a subsoil horizon, is commonly a minimum number per sample from cultivated soils not fertilized within the crop year. One hundred or more sampling units per sample may be required from soils that have recently received a broadcast application of the element under test." Such a procedure assumes that considerable variability in the nutrient status is likely to be encountered. Unless the degree of variability is actually known prior to sampling, it appears reasonable to make such an assumption.

In orchards, the area represented by a composite sample of soil is usually much smaller than in pastures, grain fields or even vegetable fields. As already noted above, it is customary in the Okanagan Valley to sample

the area occupied by one tree, or at most the area occupied by a small group of trees. This should lessen the number of individual samples necessary for making up each composite.

The data in Table 3 provide some information on the degree of variability within small orchard areas. Each sample was obtained from 4 locations at 4 trees in one row; that is, each sample was already a composite of 4. The variability among these samples was quite large. Statistical calculations on the samples taken 7 feet from the trunks of the trees revealed mean coefficients of variability* among composites of 4 as follows:

With P – 46%
With K – 20%
With Ca – 15%

These values are high largely because of the variable effects of fertilizing. The exceptionally high value with P is due partly to variable effects on the subsoil concentrations.

With this type of work, it is difficult to assess the required number of samples in a composite. If it is considered desirable to reduce the variability to at least 10 per cent, it would be necessary to make composites of 85 samples for P analysis, 16 samples for K analysis, and 9 samples for Ca analysis, on the basis of the above results. Some of the variability can undoubtedly be reduced by more careful selection of the locations. Pending further studies of this problem, the procedure adopted at the Experimental Station at Summerland is to select 8 sampling locations around any one tree, and 16 locations in a small plot.

SUMMARY

Tests were made of various steps involved in the procedure of sampling soils in orchards for nutrient studies. All tests were made in the Okanagan Valley in British Columbia, some at the Dominion Experimental Station at Kelowna, some in grower-owned orchards through the Valley. The findings may be summarized as follows:

1. *Depth of Sampling.* Samples were taken at depths of 0-8 inches, 8-24 inches, and 24-60 inches. The contents of available P and K usually decreased with depth, while Ca, free lime and pH usually increased with depth. However, the trends with depth were not consistent, so that the nutrient status of the surface soil could not be used as a reliable guide in assessing the status of the subsoil. Among the factors causing this variability were soil texture, soil depth, fertilizers applied, cultural operations, and soil erosion. It is suggested that for routine work with mature trees, samples should be taken to a depth of at least 24 inches, and that for specialized research work they should be taken to a depth of 60 inches.

* The coefficients of variability were calculated from the following formula: $C_v = \frac{100 s_x}{\bar{x}}$

in which C_v = coefficient of variability

s_x = standard deviation of x

$\bar{x}$ = mean of x

2. *Season of Sampling.* Samples were taken monthly from April 5 to December 5, at depths of 0-8 inches and 8-24 inches, at each of 32 locations. No consistent trends were found in pH, or in the contents of available P, K, or Ca. For determination of pH, P, K and Ca, no one part of the growing season appeared to be preferable to any other part.

3. *Position with Respect to Trees.* Tests were conducted to determine nutrient variations at different distances from the trunks. Where P, K or Ca fertilizers had been applied under the limbs, the P, K or Ca content of the soil decreased with distance from the tree. The same held true to some extent with P and K even where they had not been applied, while the reverse held true with Ca where it had not been applied. The pH increased with distance from the tree, while the electrical conductivity decreased. It is suggested that these variations should be taken into account in the sampling.

4. *Number of Samples in Each Composite.* Even where the sampling was restricted to the area occupied by a row of 4 trees, there was considerable variability among composites of 4 samples each. The coefficients of variability were 46 per cent with P, 20 per cent with K, and 15 per cent with Ca. To reduce the variability to 10 per cent would have required composites of 85 samples for P, 16 for K, and 9 for Ca.

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SOME CAUSES OF WASTE IN MANITOBA TABLE-STOCK POTATOES[1]

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INTRODUCTION

Manitoba-grown table-stock potatoes sold in Winnipeg during the past few years have not been found to be of particularly high market quality. They were often defective, showing undersize and irregularity, cuts and bruises, rots of various kinds, sunburn, and varietal mixture. These defects evoked the complaint, commonly heard from housewives, that Manitoba potatoes did not "keep well".

In an attempt to determine the prevalence and importance of various defects in Manitoba table-stock potatoes, a survey was made of such potatoes sold in Winnipeg retail stores during the winter seasons of 1944-45, 1945-46, and 1946-47. A study was made also of the extent to which certain common defects contributed to waste incurred in preparing tubers for cooking. The results of this survey and study are summarized and discussed in this paper.

NATURE OF SURVEY

In each month (November to March, inclusive), during the winter seasons just mentioned, a 10-lb. sample of Manitoba-grown potatoes was purchased from each of ten different grocery-stores. Usually more than ten stores had to be visited to obtain the requisite number of samples—the number of stores visited increasing as the season advanced. After each monthly collection was completed, the samples were taken to the laboratory where they were weighed, counted, and examined for varietal mixture and superficial defects. The tubers were then pared with a sharp knife, cut across to determine the prevalence of internal defects, and cleaned to remove damaged or rotting tissues. A record was kept of the weights of parings, cleanings, and healthy tissue, as well as of the prevalence of the various defects encountered.

ANALYSIS OF SURVEY DATA

Varietal Purity in Manitoba Table-stock Potatoes

The varieties principally grown in Manitoba during the years of this survey were Irish Cobbler, Warba, Bovee, Chippewa, Bliss Triumph, Katahdin, and Gold Nugget. About 75 per cent of the potato acreage in Manitoba was devoted to the first two varieties.

An examination of the potato samples collected during the survey showed that almost 50 per cent of them consisted of a mixture of varieties, mostly a mixture of Irish Cobbler and Warba. Occasionally the mixture consisted of more than two varieties.

Varietal mixture has hitherto not been considered of much importance in Manitoba, presumably because of the lack of understanding regarding its effect on cooking quality. In some localities within the United States

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(2), consumers have objected to varietal mixtures in table potatoes chiefly on the ground that the tubers cooked unevenly. Another objection in the United States was, as Sweetman (4) pointed out, that varieties of potatoes differed in the way they responded to different types of cooking. Some varieties, for example, baked well but sloughed off surface tissue when boiled. This sloughing-off of tuber tissue was considered to be wasteful.

Numbers and Sizes of Tubers

The data obtained from counts of tubers in 139 samples of potatoes collected during the present survey are summarized in Table 1. In addition to showing the proportions of samples in different numerical and percentage classes, this table shows that the average number of tubers in a sample was 33.1 and that the mean tuber weight for individual samples ranged from about 16.0 to 2.5 ounces per tuber. The number of tubers per sample actually ranged from 14 to 61, and the mean tuber weight for the whole survey was 4.6 ounces.

TABLE 1.—VARIATION IN THE NUMBER OF TUBERS IN INDIVIDUAL 10-LB. PACKAGES OF MANITOBA POTATOES PURCHASED IN WINNIPEG

Number of tubers in class	No. samples in class				Percentage samples in class				Range in mean weight per tuber (oz.)
	1944-45	1945-46	1946-47	Total	1944-45	1945-46	1946-47	Mean	
10–14	0	1	0	1	0.0	2.5	0.0	0.7	16.0–11.4
15–19	1	3	2	6	2.0	7.5	4.0	4.3	10.6– 8.4
20–24	7	7	3	17	14.2	17.5	6.0	12.2	8.0– 6.6
25–29	8	6	10	24	16.3	15.0	20.0	17.2	6.4– 5.5
30–34	9	6	11	26	18.3	15.0	22.0	18.7	5.3– 4.7
35–39	11	9	16	36	22.4	22.5	32.0	25.9	4.5– 4.1
40–44	7	5	5	17	14.2	12.5	10.0	12.2	4.0– 3.6
45–49	3	3	0	6	6.1	7.5	0.0	4.3	3.5– 3.3
50–54	2	0	1	3	4.1	0.0	2.0	2.1	3.2– 3.0
55–59	0	0	1	1	0.0	0.0	2.0	0.7	2.9– 2.7
60–64	1	0	1	2	2.0	0.0	2.0	1.4	2.6– 2.5
Total no. of samples	49	40	50	139					
Mean no. of tubers in sample	34.1	31.1	33.6	33.1					

The fact that the number of tubers in a potato sample of a given weight is inversely proportional to tuber size has considerable bearing on the amount of paring waste for that sample. It has been calculated that, with a paring of only 1/16 inch in thickness, the volume of tuber tissue lost during the process of paring is 9.1, 11.0, 18.9, and 33.0 per cent for spherical tubers 4, 3, 2, and 1 inch, respectively, in diameter. With a paring 1/8 inch in thickness, the loss for tubers of the sizes given is 17.6, 22.9, 33.0, and 57.8 per cent, respectively. If the tubers are elongate or flattened in shape, or irregular, the loss from paring is correspondingly larger.

In paring the potatoes collected during the present survey, an attempt was made to reduce paring waste to a minimum but, nevertheless, the paring waste in individual samples ranged from 13.5 to 26.2 per cent, with an over-all average of 20.0 per cent. The mean paring waste for the monthly collections (Table 2) ranged from 17.3 to 23.4 per cent.

It has already been mentioned that the average tuber weight for the whole of the present survey was 4.6 ounces. This weight appears low when compared with that (5.5 ounces) found by Rinear (2) to be most desired by consumers in certain Atlantic Coast cities, and even more so when compared with the still larger size preferred in the Midwest (1). If the weight preferred in the Atlantic Coast cities is taken as a standard, then from Table 1 it can be calculated that only 35.9 per cent of the samples, on the average, contained tubers of about the right weight (4.7 to 6.4 ounces). In 18.2 per cent of the samples the average tuber weight was too high, and in 45.9 per cent it was too low. Presumably, therefore, the paring waste in the last-mentioned group of Manitoba samples was unnecessarily high.

TABLE 2.—PREVALENCE OF DEFECTS IN MANITOBA-GROWN POTATOES AND LOSS IN TUBER WEIGHT FROM PARING AND REMOVING DAMAGED PARTS

Season	Date sampling	Stores entered to obtain 10 samples	Percentage of damaged tubers[1]				Percentage loss in weight[1]		
			Late blight	Ring rot	Cracks and bruises	Other defects[3]	From paring	From cleaning[4]	Total
1944-45	Nov. 4	10	3.9	0.6	38.0	19.6	?	?	24.6
	Dec. 5	13	5.1	3.4	27.3	13.5	17.6	8.6	26.2
	Jan. 4	18	1.9	4.5	45.1	4.8	19.9	7.4	27.3
	Feb. 5	19	0.3	2.6	35.5	15.1	20.7	3.8	24.5
	Mar. 6	25	3.1	5.3	21.2	5.1	21.6	6.2	27.8
	Mean		2.8	3.2	33.5	11.6	19.9	6.5	26.0
1945-46[2]	Nov. 5	10	1.2	9.4	33.9	6.1	18.4	12.1	30.5
	Dec. 4	12	1.1	7.7	23.0	4.0	18.1	8.7	26.8
	Jan. 7	15	0.3	8.7	31.7	1.4	17.9	9.6	27.5
	Feb. 6	42	0.1	1.7	41.2	3.9	17.3	7.7	25.0
	Mar. 5	40	—	—	—	—	—	—	—
	Mean		0.6	6.8	32.4	3.8	17.9	9.5	27.5
1946-47	Nov. 4	10	0.0	1.8	30.6	23.4	20.5	4.6	25.1
	Dec. 3	12	0.0	5.8	26.0	5.5	21.0	6.1	27.1
	Jan. 7	17	0.3	7.0	45.0	18.3	20.8	11.5	32.3
	Feb. 6	18	0.0	9.6	36.2	13.5	23.4	6.9	30.3
	Mar. 5	18	0.0	5.1	35.6	8.7	21.0	7.5	28.5
	Mean		0.0	5.8	34.7	13.8	21.3	7.3	28.6
Mean			1.1	5.2	33.5	9.7	20.0	7.7	27.7

[1] Mean for ten 10 lb. lots of tubers obtained during each collection.
[2] No Manitoba-grown potatoes could be found in stores on March 5, 1946.
[3] Greening, hollow heart, deep scab, insect injury, etc.
[4] Cleaning waste was that obtained by removing damaged parts of tubers after ordinary paring.

Prevalence and Amount of Waste from Mechanical Injury, Rotting, Sunburn, and Related Defects

The principal tuber defects in the Manitoba table-stock potatoes examined during the present survey were mechanical injuries, rotting from bacterial ring rot, late blight, bacterial and fungus soft rots, sunburn, hollow heart, stem-end and vascular browning, and freezing. Mechanical injuries, bacterial ring rot, and soft rots were comparatively abundant each year of the survey. Rotting from late blight was encountered frequently only during the 1944-45 season. Sunburn, frequently found each season, seemed to be of two types. In one type, the tubers were green only on one side, the result of exposure to sunlight in the field. In the other type, the tubers were more or less green all over, due to prolonged exposure to daylight while in grocery store bins. The amount of freezing injury, as well as of internal discoloration resulting from excessively cold storage-temperatures was considerable, particularly in the January collection of the 1946-47 season. Other defects, such as wire-worm holes, deep scab, and hollow heart were comparatively rare.

The prevalence of the major types of injuries and the resulting waste (determined by removing and weighing the damaged tissues after the tubers had been pared) is shown in Table 2. This table shows the averages for separate monthly collections of ten samples each, but not the data for individual samples. In the latter the percentages of tubers affected were: late blight, up to 37.8 per cent; cracks and bruises, up to 100 per cent; bacterial ring rot, up to 27.6 per cent. The total waste from these diseases and injuries, while shown to range only from 3.8 to 12.1 per cent (monthly averages in Table 2), actually ranged from almost nothing to nearly 40 per cent in individual samples.

Economic Importance of Waste in Manitoba Table-stock Potatoes

In Table 3 are shown the numbers and percentages of potato samples collected in this survey that fell into various classes differing in the amount of waste from paring and cleaning, and from cleaning alone. In the majority (86.8 per cent) of the samples the total waste ranged from 20.1 to 35.0 per cent. In some of the samples the total waste was almost 50 per cent, while only in a very few samples was it lower than 35 per cent. Table 3 shows, too, that although in 76.6 per cent of the samples the waste from cleaning alone was less than 10 per cent, in some of them it was considerably higher. A tuber sample with a relatively large amount of waste from cleaning is shown in Figure 1.

It is evident that in the preparation of potatoes for cooking some degree of waste, even the small amount resulting from paring reasonably large tubers, is unavoidable. Avoidable waste, resulting from the presence of defects in the tubers, may on the other hand reach considerable proportions. Some indication of the magnitude of the waste encountered during this survey, expressed in terms of the price actually paid for the tubers, is given in Table 4. The data presented disclose that the loss to consumers ranged from 1.6 to 103.2 cents per hundredweight of potatoes purchased. In over 75 per cent of the samples examined the loss exceeded 10 cents per hundredweight. This table shows, too, that the average loss for the 1944-45, 1945-46, 1946-47 seasons was 17.9, 26.5, and 21.2 cents per hundredweight, respectively.

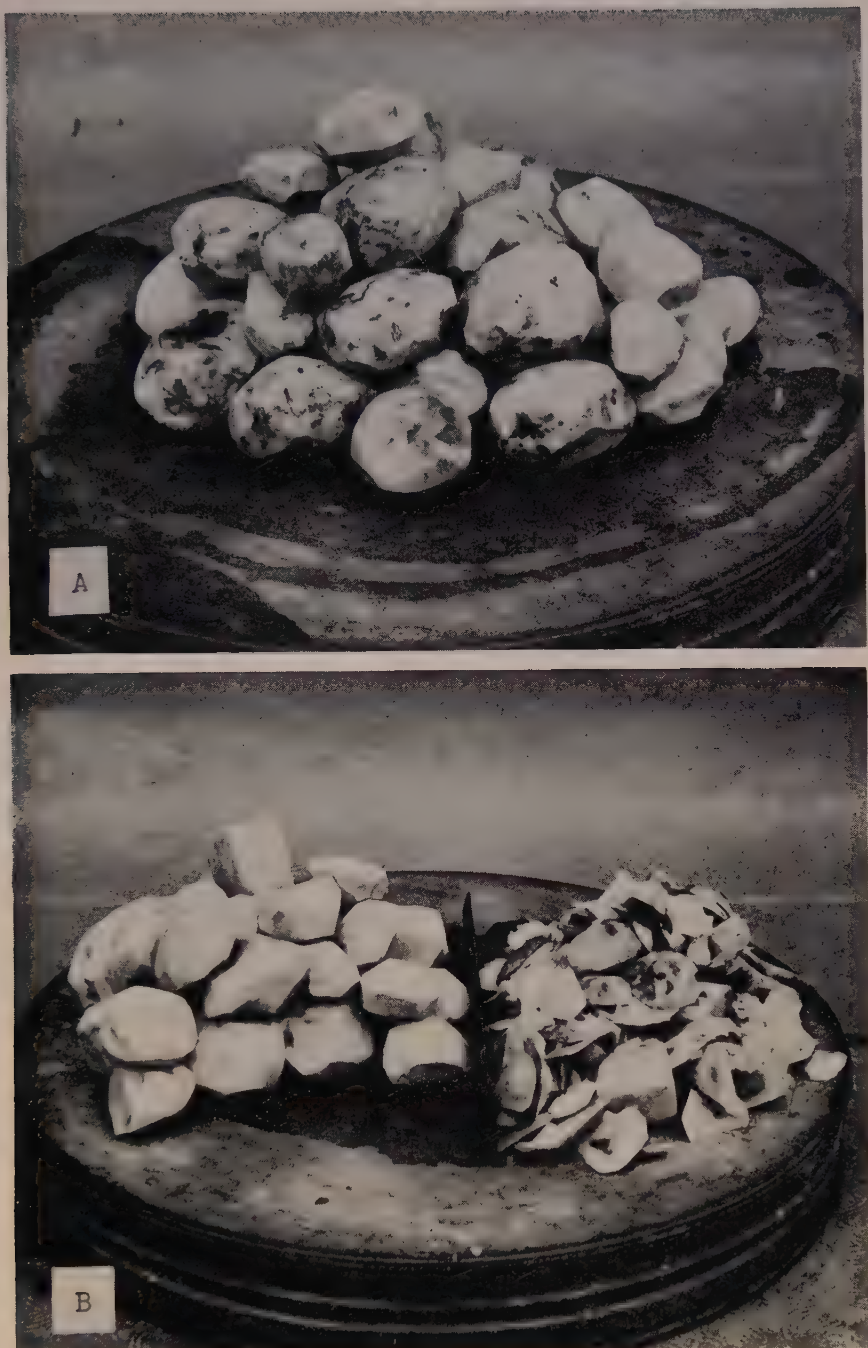

FIGURE 1. Tuber lot No. 4 of January, 1947, sampling.
A. Appearance of tubers after paring.
B. Edible residue (*left*) and waste (*right*) after cleaning of pared tubers.

TABLE 3.—NUMBERS AND PERCENTAGES OF POTATO SAMPLES AT DIFFERENT LEVELS OF WASTE FROM PARING AND CLEANING[1]

Kind of waste	Percentage of waste	Number of samples				Percentage of samples			
		1944-1945	1945-1946	1946-1947	Total	1944-1945	1945-1946	1946-1947	Mean
Total of paring and cleaning waste	0.1– 5.0	0	0	0	0	0.0	0.0	0.0	0.0
	5.1–10.0	0	0	0	0	0.0	0.0	0.0	0.0
	10.1–15.0	0	0	0	0	0.0	0.0	0.0	0.0
	15.1–20.0	2	3	0	5	4.1	7.5	0.0	3.6
	20.1–25.0	21	12	13	46	42.7	30.0	26.0	33.0
	25.1–30.0	17	13	21	51	34.6	32.5	42.0	36.6
	30.1–35.0	7	8	9	24	14.2	20.0	18.0	17.2
	35.1–40.0	2	4	5	11	4.1	10.0	10.0	7.9
	40.1–45.0	0	0	1	1	0.0	0.0	2.0	0.7
	45.1–50.0	0	0	1	1	0.0	0.0	2.0	0.7
	Total	49	40	50	139	100.0	100.0	100.0	100.0
Cleaning waste only[2]	0.1– 5.0	22	6	21	49	56.4	15.0	42.0	37.9
	5.1–10.0	12	19	19	50	30.7	47.5	38.0	38.7
	10.1–15.0	3	8	5	16	7.7	20.0	10.0	12.4
	15.1–20.0	0	7	3	10	0.0	17.5	6.0	7.7
	20.1–25.0	1	0	1	2	2.5	0.0	2.0	1.5
	25.1–30.0	0	0	1	1	0.0	0.0	2.0	0.7
	30.1–35.0	0	0	0	0	0.0	0.0	0.0	0.0
	35.1–40.0	1	0	0	1	2.5	0.0	0.0	0.7
	Total	39	40	50	129	100.0	100.0	100.0	100.0

[1] Cleaning waste was that obtained by removing damaged parts of tubers after ordinary paring.
[2] Cleaning waste alone was not determined for the first sampling of 1944-45 season, this accounting for the lower total number of samples.

Since it has been determined (3) that, under conditions of an adequate diet, the annual per capita consumption of potatoes is only about 155 pounds, the annual loss from tuber wastage borne individually by the consumer in Manitoba is not likely to be very large. If, however, the

TABLE 4.—LOSS (CENTS PER HUNDREDWEIGHT OF POTATOES PURCHASED) TO CONSUMER FROM REMOVAL OF DAMAGED TUBER TISSUE IN INDIVIDUAL SAMPLES

Date of sampling	Sample number[1]										Mean for season
	1	2	3	4	5	6	7	8	9	10	
Dec. 1944	20.7	1.6	1.9	3.3	17.0	33.6	4.8	103.2	22.9	13.6	
Jan. 1945	11.2	32.3	13.2	19.9	32.3	28.6	11.4	12.7	23.4	10.0	
Feb. 1945	14.5	13.6	17.3	11.1	5.9	7.3	15.2	8.6	8.9	7.9	17.9
Mar. 1945	33.3	35.6	7.0	27.0	2.7	14.8	12.1	7.4	32.0	—	
Nov. 1945	36.9	40.4	17.4	50.1	42.2	21.1	44.4	19.6	26.2	24.5	
Dec. 1945	24.3	50.5	15.9	6.6	12.0	24.2	20.4	28.1	39.2	10.3	
Jan. 1946	15.9	25.2	26.6	33.9	36.8	48.0	23.3	32.0	24.5	16.6	26.5
Feb. 1946	34.8	13.8	29.1	24.1	17.8	35.9	10.8	22.1	26.5	10.6	
Nov. 1946	16.2	8.8	4.2	8.6	13.5	5.5	6.1	11.3	23.8	21.7	
Dec. 1946	9.6	8.3	12.0	39.9	10.7	4.2	25.8	28.4	6.4	18.8	
Jan. 1947	68.1	22.0	15.8	79.3	27.4	19.7	22.5	52.8	13.0	14.2	21.2
Feb. 1947	16.5	13.9	10.4	12.2	27.3	36.2	15.1	50.2	19.0	7.7	
Mar. 1947	19.6	40.1	24.5	24.5	19.4	21.7	12.8	10.6	57.7	3.9	

[1] Sample No. 4, collected in January, 1947, is shown in Figure 1.

calculations of loss are based on the amount of potatoes produced annually in Manitoba, the loss assumes an important magnitude—$247,418 for the 1944 crop; $397,500 for the 1945 crop; and $257,580 for the 1946 crop.

DISCUSSION

From the data collected during the present survey it would appear that the principal defects (mechanical injuries, rots, sunburn, undersize, varietal mixtures) occurring in Manitoba table-stock potatoes are preventable—at least to a practical extent. The abundance of mechanical injuries in potatoes can certainly be much reduced if the grower exercises care during harvesting and subsequent handling in storage. This care is important since even very minute cracks in freshly-dug tubers tend to enlarge, and, under dry conditions, cause the tubers to lose moisture and shrink to an unnecessary degree. Also, various tuber-rotting micro-organisms may enter through the cracks, resulting in serious wastage of potatoes in storage. Careless handling of the tubers in transit damages them also, but the resulting loss is generally borne by the jobber, the retailer, and the consumer, and not by the producer. Losses from tuber-rotting as a result of late blight or bacterial ring rot are to some extent a consequence of inadequate attention to the crop in the field as well as in storage. Late blight can usually be controlled by fungicidal sprays in the field, but, when it is not completely controlled by this method, rotting of tubers from the disease can be reduced by postponing harvesting of the crop for several days after the vines have been killed by frost. Bacterial ring rot may be reduced to a negligible amount by the use of disease-free seed and by proper attention to storage and tool sanitation. Sunburn of the tubers can be prevented by adequate hilling of potato plants after harvest, and by shielding the tubers from sunlight while in storage. The cure for undersize and varietal mixture is too obvious to need any discussion here.

Other, not easily preventable, tuber defects, such as second growth, external cracks, hollow heart, and internal brown spot, fortunately do not occur often in Manitoba. When they do appear they reduce the market quality of table-stock potatoes as seriously as do the various preventable defects.

The abundance of tuber defects in Manitoba table-stock potatoes during the period of the survey suggested a need for potato-grading regulations designed to protect the consumer, and also to provide a premium for carefully-handled tubers. It is gratifying to learn that recently (1947) such grading regulations have been established.

SUMMARY

A survey, intended to reveal the principal causes of waste in Manitoba-grown table-stock potatoes, was carried out during the three winter seasons 1944-45, 1945-46, and 1946-47. Data concerning the kinds and amounts of waste were obtained from a study of tuber samples purchased in Winnipeg grocery stores.

About 50 per cent of the samples collected consisted of mixed varieties. In 45.9 per cent of the samples the average weight of the tubers was below the optimum desired by urban consumers in certain Atlantic Coast cities.

Waste from paring alone averaged 20 per cent by weight but ranged from 13.5 to 26.2 per cent. Waste from rotting, internal discoloration and related defects, averaged 7.7 per cent but varied from a trace to almost 40 per cent. This waste resulted in a considerable monetary loss to consumers, the loss ranging from 1.6 to 103.2 cents per hundredweight of potatoes purchased. In over 75 per cent of the samples examined the loss exceeded 10 cents per hundredweight.

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SOME EFFECTS OF FEEDING SYNTHETIC THYROPROTEIN TO DAIRY COWS[1]

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INTRODUCTION

It is a well established fact that the thyroid gland, through the secretion of its active principle, thyroxine, regulates the metabolism of vertebrates. Experimental evidence shows that parenteral or oral administration of thyroxine, either in the form of dried thyroid or as artificially formed thyroprotein causes an increase in metabolic activity. Changes in milk secretion and other treatment effects on the metabolism of dairy cows are synopsized in the following partial literature review.

Cows injected with thyroxine have been found to give increased milk and milk fat (1, 13, 18, 34). The effect of this treatment on milk solids-not-fat was not consistent. No important alteration of the nature of milk fat was observed.

The controlled iodination of casein, blood serum, soybean and ground nut protein produces compounds which have been described variously as iodinated casein, thyrolactin and thyroprotein. These synthetic materials possessing thyroxine-like activity have been shown to increase milk yield and butterfat and to be responsible for other metabolic changes. The feeding of iodinated ground nut protein to cows at the rate of 50 gm. daily has been found to increase milk yield by 35 per cent and milk fat by 54 per cent. No permanent damage to the animals was shown (5). When iodinated casein was fed to cows in daily doses of from 1 to 100 grams for varying periods of time, increases in milk yield ranging from 8.5 to 33 per cent and butterfat changes varying from no effect to an increase of 50 per cent have been reported (2, 6, 7, 8, 9, 19, 28, 29, 31, 35, 37). Similar treatment has been stated to cause slight increases in milk solids-not-fat (6, 37) but no change in total nitrogen (19, 38). Reported effects on the casein and ascorbic acid content of milk are conflicting, some workers stating that no appreciable changes occur, (18, 38), other investigators reporting that these constituents are affected (2, 37). No change in the carotene or ascorbic acid content of cows' blood plasma was found after feeding iodinated casein (19) but respiration and pulse rates were increased (19, 37). Body weight losses have been stated to depend on dosage and length of treatment (19, 23, 37). The effectiveness of iodinated casein depends on the route of administration, parenteral injection being 20 times as effective as oral feeding (36).

The above references show that significant physiological responses are obtained by the administration of iodinated casein but the reported effects are variable and conflicting. This experiment was undertaken to study

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[4] Agricultural Scientists, Division of Animal Husbandry.

the effects of the closely controlled oral administration of iodinated casein to dairy cows at a definite stage of lactation and under Canadian conditions. It was considered important to determine whether body weight losses due to increased metabolic activity could be inhibited at a relatively high level of nutrition. Particular studies were made of treatment effects on the milk yield, milk composition and health of the test animals.

EXPERIMENTAL

Determination of Physiological Activity of Thyroproteins

Before thyroproteins of unknown potency can be applied in feeding trials with dairy cattle it is necessary to have a measurement of their physiological activity. Since such activity depends on the thyroxine content, assay methods are directed toward the determination of this component. Measurement of the influence of the thyroxine content of thyroproteins on the metabolism of laboratory animals may be used as an index of potency or, alternatively, thyroxine can be measured by the determination of its iodine content, since iodine is part of the thyroxine molecule.

In this experiment an attempt was made to evaluate the potency of the thyroprotein to be used by measuring its effect on the thyroid gland weights of cross-bred chicks. The procedure used depended on the preventive effect of thyroxine on the goitrogenic action of thiouracil. The amount of thyroxine required to prevent thiouracil-induced hypertrophy provides a reference for measuring the potency of the thyroprotein. This method may not accurately measure the actual amount of thyroid hormone involved but it does allow a measurement of the comparative effects of thyroprotein and thyroxine.

The above procedure has not proved to be suitable because of the extreme variability of chick thyroid gland weights and also because of the too-gradual slope of the dose-response curve. Several facts, however, relating to the application of this technique may be of interest. It was found that the goitrogenic action of thiouracil added to the ration is more effective at a level of 0.050 per cent than at a level of 0.1 per cent, the value which frequently has been reported as producing the maximum effect. Administration of this agent in the dry ration has been found to be more effective than its solution in the drinking water. In applying this assay procedure it has also been found that KI in the diet, even in low amounts, has quite an appreciable antigoitrogenic effect when given with the goitrogenic agent, thiouracil. Further investigations are being made.

The iodine content of thyroproteins has been shown to be directly related to the physiological activity (10, 11, 15, 16, 21, 24, 33, 39). Two methods, those of Harington and Randall (20) and Reineke *et al.* (32) involving the determination of the iodine content as the criterion of potency have been applied.

The first method involves caustic hydrolysis and subsequent determinations of the total and the acid-soluble iodine. The acid-insoluble iodine, determined by difference, may represent the thyroxine-bound iodine but some workers (4, 22) have found that this value includes more than thyroxine-bound iodine. It has also been shown that the caustic solution which is used in this method causes approximately 17 per cent destruction

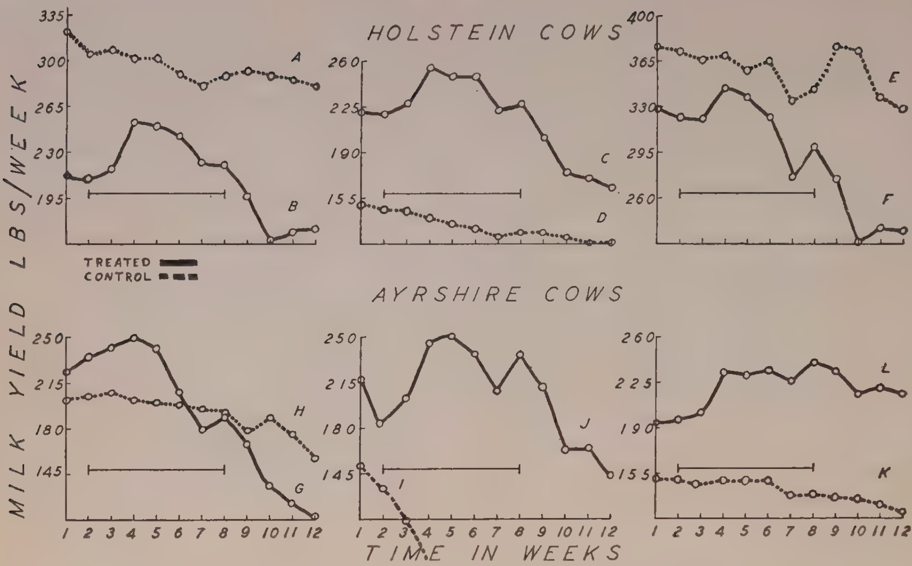

FIGURE 1. The effect of thyroprotein on milk yield.

of the thyroxine while a more dilute solution does not give complete hydrolysis. Analysis of the sample under investigation by this method gave a value of 4.35 per cent expressed as thyroxine and not corrected for loss. Since this method is not apparently specific for thyroxine iodine, the method of Reineke *et al.* (32), which has been reported to be more precise, has been applied.

The method of Reineke *et al.* involves hydrolysis with 40 per cent baryta solution instead of caustic solution. Then, following the adjustment of the hydrogen ion concentration, the hydrolysate is extracted with butanol which not only removes all of the thyroxine but also a large amount of the non-thyroxine organic iodine and decomposition products. Consequently the butanol extract must be treated with several portions of caustic solution in order to remove thyroxine selectively. The purified extract is evaporated to dryness. For this procedure, the use of a surface evaporator has been found to be more efficient and time-saving than steam-bath evaporation. Fusion of the butanol residue with caustic is followed by combustion. At this stage it was found that a combustion period of fifteen minutes at a controlled temperature of 400° C., as recommended by Doery (12), gave more consistent results than the combustion conditions suggested in the original method. The iodine content of the fused material was determined by titration as in the Harington and Randall method. A further modification introduced, the use of sodium starch glycollate as indicator (26) instead of starch, was found to give a sharper end point. Application of this method, including the modifications mentioned, gave a thyroxine value of 3.07 per cent for the thyroprotein under trial.

The procedure of Reineke *et al.* for the determination of iodine is preferred to that of Harington and Randall since it has been reported to be in better agreement with biological tests.

Blaxter (7), using material having approximately the same physiological potency as the thyroprotein under trial, found that a 20 gm. daily

dose was slightly too high for some breeds of cattle. Therefore it was considered that a lower dosage level, based on the thyroxine value of 3.07 per cent, would be satisfactory for this experiment.

Feeding Trial Procedure

Six Holstein-Friesian and six Ayrshire cows were matched in pairs as shown in Table I. To avoid the influence of early lactation and pregnancy on milk yield, animals were selected which would be approximately in mid lactation for the period of the test.

TABLE 1.—ALLOTMENT OF COWS

Designation of animal	Treatment	Age	Previous lactations	Body weight	Time since calving	Time pregnant	Weekly milk yield	Butter fat
		yr.	no.	lb.	mo.	mo.	lb.	%
Holstein								
A	Control	5	2	1342	5	3	351	3.4
B	Treated	4	1	1332	5	2	226	3.4
D	Control	4	1	1345	5	2	167	3.9
C	Treated	4	1	1265	5	2	234	3.9
E	Control	7	4	1470	2	0	411	3.6
F	Treated	6	3	1385	3	0	373	3.8
Ayrshire								
H	Control	4	0	1140	4	0	208	4.2
G	Treated	4	1	1150	4	1	227	4.2
I	Control	5	2	1189	5	1	207	4.5
J	Treated	5	2	1177	5	0	231	4.6
K	Control	3	0	980	4	0	165	3.9
L	Treated	3	0	987	4	0	189	4.4

The experiment was divided into a 2-week preliminary period, a 6-week treatment period and a 4-week post treatment period.

Rations based on Morrison's "standard rate" (25), consisting of hay, meal and silage, were weighed and fed individually and any residues were weighed back. The meal mixture was calculated and made up as shown in Table 2.

TABLE 2.—PROPORTIONS OF INGREDIENTS IN MEAL MIXTURE

Grain	Amount	Digestible protein	Total digestible nutrients
	lb.	%	%
Ground Oats	200	9.4	71.5
Ground Barley	200	9.3	78.7
Ground Wheat	100	11.3	83.6
Wheat Bran	100	13.1	70.2
Soya Beans	150	32.8	86.2
Weighted mean content		14.8	77.8

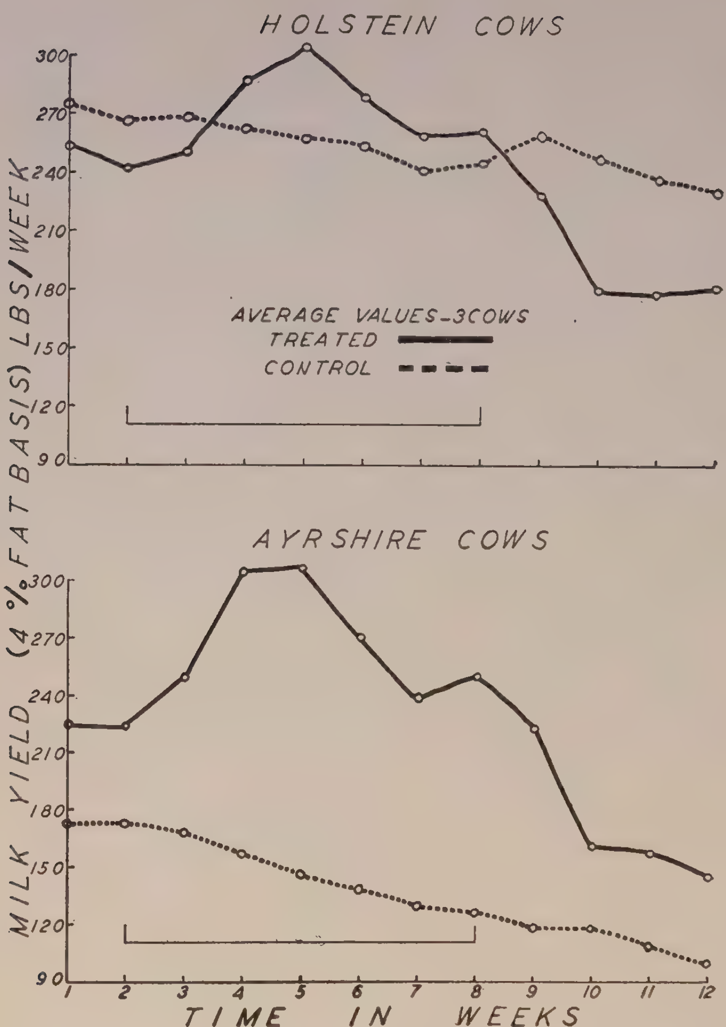

FIGURE 2. Combined effect of thyroprotein on milk and butterfat expressed as fat-corrected milk.

Two pounds of grain in addition to the "standard rate" were fed to counteract to some extent an expected loss of body weight. Body weight loss due to thyroprotein administration has been reported by Blaxter (7). The roughage consisted of good quality hay (alfalfa 30 per cent, clover 30 per cent, timothy 40 per cent) and corn silage.

Each treated cow received 7.5 grams of thyroprotein twice daily. This dosage was based on chemical analysis of the material and on previous work (7, 32). An enhanced physiological effect was expected from the administration of divided doses instead of one daily dose. The material used was "Protamone", an iodinated casein, prepared by the addition of iodine to casein under carefully controlled conditions and possessing thyroxine-like activity. Processing details have been described (27, 30).

The three ration components were analysed at the midpoint of each experimental period. Milk yields were recorded twice daily and weekly

composite milk samples composed of aliquots from each cow were analysed for butterfat, lactose, total nitrogen and ash (3).

Pulse and respiratory rates, body and barn temperatures were recorded three times weekly throughout the experiment. Body weights of the cows were determined at a regular time each week.

RESULTS

The thorough incorporation of the thyroprotein in the grain ration and the pouring of this mixture over the ensilage seems to have overcome the difficulty of feed refusal reported by Blaxter (7) and Deakin (9). Some cows at a high level of production were unable to consume all of the ration offered and in such cases the ration was adjusted to an amount that could be readily consumed.

Table 3 gives the average analytical values of three samplings of the ration components.

TABLE 3.—CHEMICAL ANALYSES OF FEEDS

Component	Dry matter	Protein (N×6.25)	Nitrogen-free extract	Ether extract	Fibre	Ash
	%	%	%	%	%	%
Meal mixture	87.96	16.65	56.11	4.60	7.29	3.31
Hay	90.49	11.56	40.47	1.07	32.38	5.01
Ensilage	21.20	1.69	11.06	0.24	6.95	1.26

The total digestible nutrients were calculated from these analyses using the digestion coefficients of similar feeds tabled in "Feeds and Feeding", Morrison (25). Table 4 gives the mean weekly digestible nutrient consumption of each animal for each period of the experiment, and the total consumption for the twelve-week period.

TABLE 4.—DIGESTIBLE NUTRIENT CONSUMPTION

Designation of animal	Treatment	Mean weekly consumption			Total consumption
		Pre-treatment	Treatment	Post-treatment	12 weeks
		lb.	lb.	lb.	lb.
Holstein					
A	Control	164.7	167.1	166.3	1997
B	Treated	145.4	153.5	143.6	1786
D	Control	124.3	116.1	116.6	1401
C	Treated	143.9	148.5	143.1	1751
E	Control	162.9	163.5	169.9	1987
F	Treated	165.8	176.2	157.9	2020
Ayrshire					
H	Control	124.3	132.3	127.6	1553
G	Treated	137.9	144.5	121.3	1628
I	Control	120.8	94.9	84.6	1150
J	Treated	143.3	151.3	140.0	1755
K	Control	101.3	109.2	108.9	1293
L	Treated	110.6	121.6	126.8	1458

This table shows the relatively high total digestible nutrient consumption of all cows and some increase in the consumption for the treated group during the treatment period.

The Effect of Thyroprotein on Milk Yield

A comparison of the individual lactation curves given in Figure 1 shows a marked increase in milk production due to the administration of thyroprotein. The maximum production rate was reached early in the treatment period.

Since a change in butterfat production occurred concurrently with a change in milk yield, these combined effects are shown in Table 5 which expresses milk yield on a 4 per cent fat basis according to Gaines' formula (17).

Table 5.—The effect of thyroprotein feeding on milk production (expressed as fat corrected milk)

Designation of animal	Treatment	Weekly average production			Percentage differences		Total production
		Pre treatment	Treatment	Post treatment	Pre treatment to treatment	Treatment to post treatment	12 weeks
		lb.	lb.	lb.	%	%	lb.
Holstein							
A	Control	307.3	300.3	290.7	−2.3	−3.2	3579
B	Treated	209.5	246.9	171.5	17.8	−30.5	2587
D	Control	142.3	132.8	123.3	−6.7	−7.1	1575
C	Treated	212.4	253.0	173.4	19.1	−31.5	2637
E	Control	353.8	329.3	314.6	−6.9	−4.5	3942
F	Treated	323.0	321.6	230.3	−0.4	−23.4	3497
Ayrshire							
H	Control	208.2	214.9	181.9	3.1	−15.4	2434
G	Treated	255.7	270.6	147.1	5.8	−45.6	2723
I	Control	146.4	53.2	8.4	−63.5	−84.2	646
J	Treated	226.0	275.6	177.1	21.9	−35.7	2814
K	Control	164.5	163.7	143.1	−0.5	−12.6	1883
L	Treated	191.9	270.9	191.0	41.2	−29.5	2774

The marked differences between control and treated cows in this table show that thyroprotein has increased the production of fat-corrected milk. This fact is further exemplified in the sharp decline in production which occurs after the withdrawal of the activating agent.

The treatment effects are presented in a different manner in Figure 2, which compares the control and treated cows of each breed, and shows a more pronounced response by Ayrshires than by Holsteins. The maximum rate of production, which occurred at the third week of treatment, was followed by a rapid decline and normal levels were reached four weeks after termination of treatment.

The evidence presented indicates clearly that the administration of thyroprotein has stimulated production.

PLATE 1. Loss of body weight due to thyroprotein treatment. Cow G *(left)* has been under treatment for 6 weeks.

PLATE 2. Recovery of body weight. Four weeks after withdrawal of thyroprotein, cow G *(left)* has recovered 65 per cent of weight loss.

Feed Consumption in Relation to Milk Yield

Observed treatment effects of thyroprotein administration were an increase in milk production and a decrease in body weight. Ration adjustments for these changes were made on a week-to-week basis by reducing roughage according to body weight loss and by increasing the grain component according to increases in milk production. The net effect of these alterations was an intake of 10,398 lb. of nutrients by the treated cows as compared to 9,381 lb. by the controls. Since milk yield is influenced by the level of feeding (40) and, as shown in Table 4, the animals were maintained on a relatively high level of nutrition, it was considered desirable to determine to what extent the higher nutrient level of the treated animals was responsible for their increased production. Calculations from consumption and production data reveal that for each 100 lb. of digestible nutrients consumed the milk yields, calculated on a 4 per cent fat basis, averaged 164 lb. for treated cows and 150 lb. for controls. The average net body weight loss for the treated cows over the twelve-week period was 45 lb. while the average gain for the controls was 28 lb. Therefore, it is concluded that the increase in production per unit of nutrient consumption is a result of feeding thyroprotein and is secured through a temporary decrease of body weight.

The Effect of Thyroprotein on Milk Composition

The effect of thyroprotein treatment was also apparent in significant changes in milk composition.

BUTTERFAT

Fat determinations on representative weekly samples were made by two methods, Babcock and Mojonnier (Roese-Gottlieb) (3). The former

TABLE 6.—THE EFFECT OF THYROPROTEIN FEEDING ON BUTTERFAT PERCENTAGE

Designation of animal	Treatment	Weekly average butterfat percentage			Per cent changes	
		Pre treatment	Treatment	Post treatment	Pre treatment to treatment	Treatment to post treatment
Holstein						
A	Control	3.9	4.1	4.1	+0.2	0.0
B	Treated	3.9	4.4	3.8	+0.5	−0.6
D	Control	3.7	3.9	4.0	+0.2	+0.1
C	Treated	3.8	4.4	3.8	+0.6	−0.6
E	Control	3.6	3.5	3.3	−0.1	−0.2
F	Treated	3.9	4.3	3.7	+0.4	−0.6
Ayrshire						
H	Control	4.2	4.6	4.5	+0.4	−0.1
G	Treated	4.8	5.4	4.3	+0.6	−1.1
I	Control	4.2	3.1	1.7	−1.1	−1.4
J	Treated	4.9	5.4	4.2	+0.5	−1.2
K	Control	4.6	5.0	4.6	+0.4	−0.4
L	Treated	3.9	5.3	4.0	+1.4	−1.3

method was found to give slightly higher values and since the Mojonnier method is considered to be more accurate these values only are reported. The data in Table 6, illustrated graphically in Figure 3, reveal an increase in the butterfat percentage of all treated cows, Ayrshires showing a greater response than Holsteins. The highest values occurred at about the third week of treatment. A decline commenced even before the withdrawal of the activating agent and was accelerated on termination of treatment. The decrease in butterfat percentage immediately after cessation of treatment was variable and was not related to the initial fat concentration or to the magnitude of response to treatment. With the exception of cow I the values for the control cows are within the range of variability commonly found in a dairy herd. There was a difference in response to treatment between cows initially producing less than 10 lb. of butterfat per week and those producing a greater amount, the lower fat-producing animals showing a greater response to stimulation.

LACTOSE

Changes in the lactose concentration of the milk due to thyroprotein are insignificant as week to week variations were observed in all cows. Averages computed from analytical data are given.

TABLE 7.—AVERAGE LACTOSE PERCENTAGE

	Pre treatment	Treatment	Post treatment
	%	%	%
Control cows	4.85(4.24 – 5.24)*	4.58(2.70 – 5.10)	4.30(1.54 – 4.89)
Treated cows	4.89(4.70 – 5.36)	5.02(4.82 – 5.18)	4.88(4.67 – 5.15)

* Range of individual determinations.

The ranges shown for the control group are markedly affected by the rapid decline in lactose concentration of the milk from cow I.

TOTAL NITROGEN

Irregular variations in total nitrogen were found throughout the experiment. No effects due to thyroprotein were observed.

Total nitrogen values based on the analysis of weekly composite milks are shown by groups for each experimental period.

TABLE 8.—AVERAGE TOTAL NITROGEN PERCENTAGE

	Pre treatment	Treatment	Post treatment
	%	%	%
Control cows	0.49(0.41 – 0.57)*	0.49(0.40 – 0.58)	0.51(0.40 – 0.64)
Treated cows	0.48(0.43 – 0.53)	0.47(0.42 – 0.50)	0.49(0.43 – 0.57)

* Range of individual determinations.

MILK ASH

No significant changes occurred in the milk ash content of the milk due to treatment.

TABLE 9.—AVERAGE MILK ASH PERCENTAGE

	Pre treatment	Treatment	Post treatment
	%	%	%
Control cows	0.69(0.65 – 0.75)*	0.68(0.61 – 0.73)	0.68(0.61 – 0.77)
Treated cows	0.68(0.62 – 0.81)	0.67(0.60 – 0.74)	0.65(0.61 – 0.71)

* Range of individual determinations.

MILK SOLIDS-NOT-FAT

Milk solids-not-fat consist of lactose, nitrogenous and mineral substances and since variations in these values have been shown to be insignificant, it was not expected that changes in solids-not-fat values would be found. Observations of the analytical data show that no significant change due to treatment has occurred.

TABLE 10.—AVERAGE SOLIDS-NOT-FAT PERCENTAGE

	Pre treatment	Treatment	Post treatment
	%	%	%
Control cows	8.66(7.89 – 9.13)*	8.38(5.38 – 9.29)	8.27(5.52 – 9.38)
Treated cows	8.61(7.57 – 9.36)	8.70(8.00 – 9.45)	8.73(8.25 – 9.04)

* Range of individual determinations.

Since the solids-not-fat values were calculated on milk which varied considerably in butterfat, it was considered that calculation on a fat-free basis would eliminate the effect of such irregularities and possibly reveal changes due to treatment. However, a study of these calculations does not show any significant differences between control and treated cows.

Physical Reactions to Thyroprotein Treatment

The greatest physical effects due to treatment were loss of body weight and elevation of pulse rate. Respiratory rate and body temperature, were not measurably affected.

BODY WEIGHT

As will be seen from Figure 4 the control cows show some fluctuations in body weight with a trend toward rising values which is somewhat more accentuated in Holsteins than in Ayrshires. The upward trend is probably due to the high level of feeding which included extra meal in the regular ration.

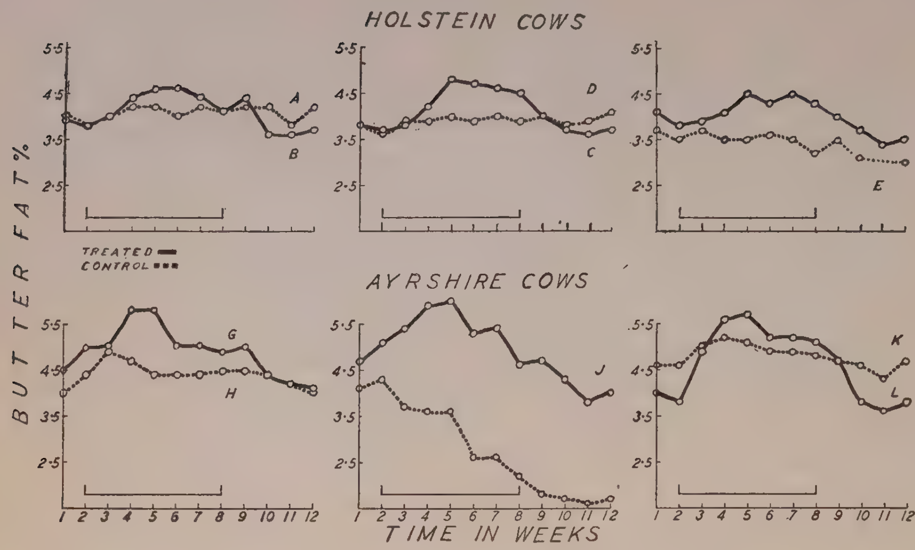

FIGURE 3. Effect of thyroprotein on butterfat production.

The changes in body weights of treated cows provide distinct contrasts to the respective controls. It will be noted that each of these cows lost weight, the decline commencing in the first week of treatment and continuing until the withdrawal of thyroprotein. Immediate and rapid weight recoveries followed. By the end of the trial only three of the treated cows had fully regained lost weight. A week after the completion of the experiment two of these animals were still below their original weights, but examination after a further short interval showed complete recovery.

The maximum and minimum body weight losses were 202 and 70 lb. representing 13.7 and 7.1 per cent respectively of pre-treatment weights.

Plates 1 and 2 illustrate these changes in body weight.

Blaxter (7) reports that extra grain was effective in preventing a considerable part of the body weight loss in iodinated casein feeding trials. In this experiment it is clear that the addition of 2 lb. of grain to the ration has not prevented loss of weight by the treated animals.

It may be concluded therefore, that even at a high level of feeding loss of body weight may be expected with the dosage of thyroprotein used.

PULSE RATE

Pulse counts were taken manually from the saphenous artery of the left hind leg. The heart beat data averaged for each week are shown in Figure 5.

The pulse rates for control cows show considerable irregularity with fluctuations of surprising magnitude in some individuals.

Pulse rates increased immediately and sharply after the administration of thyroprotein and continued to increase as treatment progressed. The response was variable, the maximum increase in rate being 36 per cent. Elevated heart action persisted throughout the treatment period but was followed by a gradual return to normal levels after withdrawal of thyro-

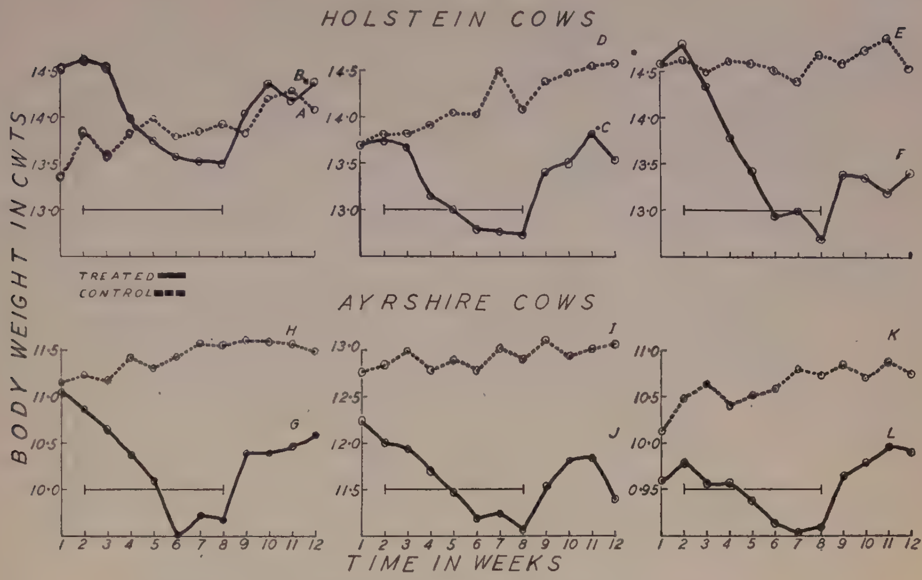

FIGURE 4. Body weight changes in thyroprotein-treated cows.

protein. The pulse rates of three cows receded below their normal levels and were still subnormal five weeks after the discontinuance of treatment. Blaxter (7), obtaining similar results, considered them to be the effects of a post-experimental depression of metabolism.

RESPIRATORY RATE

Since, as has been shown, treatment has increased metabolism, it might be expected that the resulting increased oxygen consumption would be reflected in higher respiratory rates. However, the observations have not shown any treatment effect on respiratory rate. Variations between individual control cows were as great as variations between treated and control pairs, the increases ranging from 4 to 14 respirations per minute. The average increase of 17 per cent for all cows might possibly have been due to the slowly rising average temperature of the barn.

BODY TEMPERATURE

Since the greatest difference between average weekly temperature readings for all cows did not exceed 0.9° F. and the temperature readings for control cows were as variable as those for treated animals, it can be concluded that thyroprotein administration has not affected body temperature.

Since air temperatures have been reported to affect body temperatures, records were made of air temperatures at a point 4 ft. above floor level. Barn temperatures which varied between the two extremes of 56 and 71.2° F. could not be correlated with the minor changes in the cows' temperatures. The influence of higher temperatures on body heat is reported by Gaalaas (14).

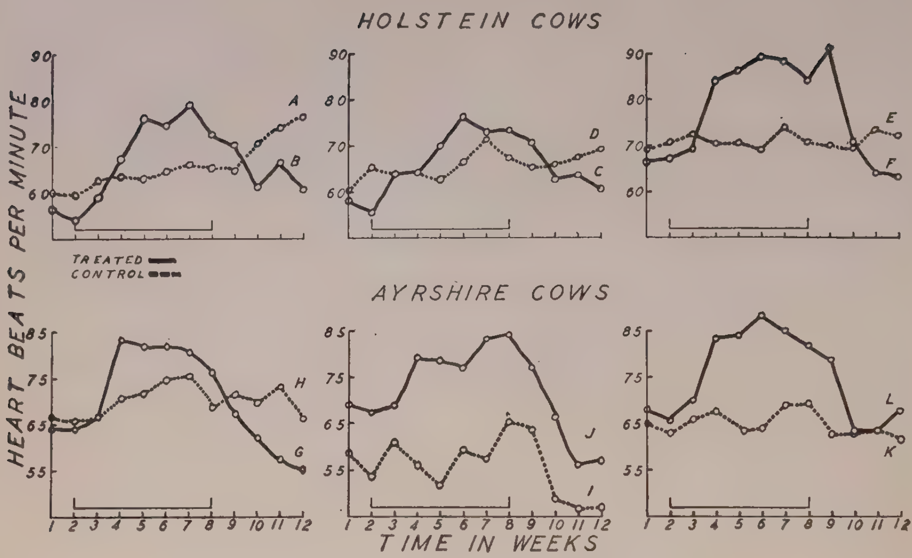

FIGURE 5. Heart rate changes in thyroprotein-treated cows.

Estrus apparently does not affect body temperature since no detectable change in body temperature could be found in cows which were in estrus during the experiment. It might be observed that two cows, which were under thyroprotein treatment, showed no irregularity in estrus cycles.

It can be concluded that body temperature is not affected by the dosage of thyroprotein used or by air temperatures in the range reported.

HEALTH

No symptoms of iodism such as mucus discharge, weakness, extreme irritability or exophthalmia were observed. These observations do not preclude the possibility that health has been affected.

The Effect of Dosage in Relation to Body Weight

Since cows with widely differing body weights all received the same daily dose of Protamone it is obvious that the dose per unit of body weight varied. To determine whether this factor had any influence on the effects being studied, pertinent comparative values are tabulated. The values given in Table 11 were computed to the end of treatment. The thyroxine dosage, expressed as grams per 100 lb. of body weight, is based on the analysis reported in a previous section.

A study of the data shows that in this experiment there is no correlation between treatment effects and body weight.

PRACTICAL CONSIDERATIONS OF THYROPROTEIN TREATMENT

From the practical viewpoint thyroprotein may be considered in relation to its effects on economy of feeding and production, on health and on milk records.

TABLE 11.—THE EFFECT OF DOSAGE IN RELATION TO BODY WEIGHT

Cow	Body weight	Protamone (daily)	Thyroxine (total)	Average change in production			Body weight loss	Average increase in pulse rate
				Milk	Butter-fat	Milk sugar		
	lb.	gm./100 lb.	gm./100 lb.	%	%	%	%	%
F	1471	1.02	1.31	−2.6	1.5	−1.3	13.7	25.3
B	1460	1.03	1.32	10.9	22.9	13.3	7.5	25.4
C	1374	1.09	1.41	8.0	26.5	11.0	7.3	30.3
J	1200	1.25	1.61	14.3	25.8	13.3	7.7	25.4
G	1086	1.38	1.78	−5.1	8.3	−9.1	11.0	18.7
L	979	1.56	2.01	16.7	57.9	28.2	7.1	20.9

Because of the short duration of this experiment, the small number of animals used, the necessary adjustment of rations as the trial progressed, and the relatively high level of feeding, it was realized that data concerning the effect of thyroprotein on economy of feeding would be of limited value. However, since the groups of cows used were considered to be representative of purebred cows, and the rations fed were standard, it was decided that it would be of some interest to calculate the amount and cost of feed consumed by both the control and treated groups of animals for the production of 100 lb. of fat-corrected milk. These figures are given in Table 12.

TABLE 12.—AMOUNT AND COST OF FEED FOR PRODUCTION OF 100 POUNDS OF FAT-CORRECTED MILK

	Meal at \$50 per ton	Hay at \$20 per ton	Silage at \$7 per ton	Cost of ration
	lb.	lb.	lb.	\$
Control Group	39	44	128	1.87
Treated Group	42	35	104	1.76

Consumption values for meal, hay and silage reflect both the increased milk production and loss in body weight resulting from thyroprotein treatment. The high cost of the feed may be explained by the relatively high level of feeding and by the current prices for feeds. The difference in the cost of feed for each group is not significant. The apparent economy in milk production obtained by feeding thyroprotein might be offset by other factors such as loss in body weight, increased pulse rate and higher metabolic rate which might possibly shorten productive life.

In a previous section it was mentioned that no specific symptoms of iodism were observed. However, the effect of thyroprotein on body weight and pulse rate during this brief trial suggests the possibility that such an agent, having the ability to increase the metabolic rate of a dairy cow to the extent found, could in longer trials have far-reaching effects on health, longevity and reproductive ability.

Thyroprotein must be considered in its relationship to the recognized testing and recording of the milk of dairy cows in Canada. Its indiscriminate use for dairy cows on test would not only affect records but, in the hands of unscrupulous breeders, could make milk testing meaningless. This statement is supported by the evidence previously given concerning the effects on milk and butterfat yields when thyroprotein is administered even for a short time and at moderate dosage levels. When it is remembered that there were no treatment effects other than increased milk and butterfat that could be checked under practical conditions the necessity for strict control of products of this nature is obvious.

SUMMARY AND CONCLUSIONS

In a three-month trial a synthetic thyroprotein, "Protamone", containing 3.07 per cent thyroxine by analysis, was fed to Holstein and Ayrshire cows at the rate of 15 gm. daily for 6 weeks and the effects were compared with paired controls.

(1) Increased milk production occurred in the early part of treatment, the maximum individual increase over initial yield being 16.7 per cent. With one exception production rates declined rapidly subsequent to treatment.

(2) Analysis of individual milk samples revealed increases in butterfat percentage varying from 0.4 to 1.4 due to treatment but no significant changes occurred in lactose, total nitrogen, ash, or solids-not-fat percentages.

(3) Milk yields calculated on a 4 per cent fat basis showed marked increases, the maximum being 41.2 per cent.

(4) Body weight losses varying from 7.1 to 13.7 per cent were observed in all treated cows despite the additional meal given.

(5) Pulse rates were markedly elevated but decreased rapidly when thyroprotein administration was terminated.

(6) Respiratory rates and body temperatures were not affected.

(7) Differences in body weight had no apparent influence on treatment effect.

(8) Contrary to expectation, no refusal of the treatment ration was encountered.

(9) No specific symptoms of iodism were observed.

From the evidence submitted it is concluded that until further knowledge of the action of thyroprotein is obtained, its use cannot be recommended. Investigations on a larger scale for longer periods are required to establish the effect of dosage levels, diets and planes of nutrition on production, health, breeding ability, successive lactations and longevity. More precise methods for measuring the biological activity of thyroproteins are necessary for effective analytical control.

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DIGESTIBILITY STUDIES WITH RUMINANTS

XII. THE COMPARATIVE DIGESTIVE POWERS OF SHEEP AND STEERS[1]

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Forbes (4) has emphasized the need for a determination of the relationship between the digestive powers of steers and sheep. He reviewed some early investigations on the subject. W. Frear (5), H. P. Armsby (1), the Mississippi Agricultural Experiment Station (10), J. M. Bartlett (2), O. Kellner, A. Köhler and W. Zielstorff (9), F. Tangl and S. Weiser (12), W. Völtz, J. Paechtner, A. Braudrexel, W. Dietrich and A. Deutschland (14), R. E. Neidig, C. W. Hickman and R. S. Snyder (11), T. S. Hamilton and T. S. Kick (6), have all carried out comparative digestion trials between steers and sheep. The feeds were, in most cases, silages and hays. There were a few experiments with grains and concentrates. The digestion trials, however, were not very extensive, nor could they lead to very definite conclusions.

There were several reasons for this unsatisfactory situation. In most cases only a few animals were used. For instance, in eight of the reports one, or at most two, animals of each species were used for comparison. In three cases three to five of each species were used. In all cases only one trial was carried out for each comparison. There were no repetitions. There were also large variations between duplicate animals when more than one was used. In a few cases the agreement could be considered satisfactory. Finally, results of all investigators were not in complete agreement. For instance, in the case of silages, two investigators reported superior digestibility of steers, one a superiority of sheep and one case was doubtful. In the case of roughages, four investigators reported a superiority of steers, one for sheep and two cases were doubtful. In the case of concentrates, in three trials the differences were too small or the error too large to determine which species was superior.

Forbes (4) carried out a comparison of sheep and steers on a more extensive scale with a large number of animals under more controlled and critical conditions. He used four rations. Two were composed of machine-dried alfalfa and a concentrate mixture in the ratio of 1 : 1; one was composed of a ration of machine-dried alfalfa and ground corn in the ratio of 1 : 2, while a fourth ration consisted of sun-dried alfalfa and ground corn in the ratio of 1 : 1. These were fed to cows and sheep using from 2 to 5 animals. Various planes of nutrition in relation to maintenance were used. Values for maintenance requirements were based on Brody's standards. Forbes concluded that, with the exception of crude fibre, sheep digested their rations in general more efficiently than steers. He suggested that published coefficients with any species should be based upon digestion trials carried out on that species. In published tables of the digestible nutrient content of feedstuffs no discrimination has been made between sheep and cattle.

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Quite recently Briggs *et al.* (3) have reported on the digestibility of dried sweet potatoes by steers and sheep. Coarsely cracked corn was used for comparison purposes. Basal rations were alfalfa hay and also a mixture of prairie hay with cotton-seed meal. Four steers and eight sheep were used. With the alfalfa hay there was no difference between the digestive powers of steers and sheep. In the case of the potatoes the steers were somewhat superior to the sheep. There was little difference between the species for corn. In one case the steers were superior. In the other case, the sheep were superior.

In view of the importance of this question it was decided in 1939 to carry out a large scale investigation on the comparative digestive powers of sheep and steers. This has now been completed. The general principle adopted for this work was to use a large number of animals and to set up the experiments in the form of randomized Latin squares. In this way allowance was made for individual animal differences. At the same time the trials on any one feed were repeated over a considerable length of time. The following experiments were carried out.

Experiment No. 1

The rations consisted of a grain mixture fed alone and then fed with corn silage. The amount of grain was kept constant while the corn silage was fed at different levels. Six grade Shorthorn steers were used. They were fed six rations—grain alone at a level of 3 kilos and then mixed rations of grain and silage with grain being kept at 3 kilos and the silage varied from 4 kilos to approximately 25 kilos. The sheep used were four Leicester-Shropshire crosses. They received the same grain ration fed alone and also fed with silage, the latter being given at three different levels. The amounts fed to the sheep were related to the amounts fed to the steers in the ratio of the 0.73 power of the live weights. The grain rations consisted of barley 3 parts, wheat bran 2 parts and linseed oil cake meal 1 part. The barley was "Ottawa Mensury" grown at the Experimental Farm. The wheat bran was obtained from the Quaker Oats Company under the trade name "Bell Brand". The oil cake meal was obtained from the Sherwin-Williams Company of Canada and was prepared by the "screw-press" method. The corn silage was a mixture of Improved Leaming and Wisconsin No. 7. In colour it was a bright greenish yellow with a sharp sweetish odour and was considered of good quality.

At the conclusion of the experiment the coefficients of digestibility of the corn silage were calculated from the mixed rations using the coefficients of grain determined when that mixture was fed alone.

Experiment No. 2

Four grade Shorthorn steers and four Leicester-Shropshire wether sheep were used. They were fed rations of hay and of hay plus oats. Comparisons between species were made of the digestibility of hay alone and of the oats calculated from the rations with hay. For the steers the hay was fed alone at a level of 7 kilos a day and the mixed ration was fed at a level of 5 kilos of hay with 3 kilos of ground oats. Sheep were fed at a level in relation to the steers according to the ratio of 0.73 power of the

TABLE 1.—COMPARISON OF MEAN COEFFICIENTS OF DIGESTIBILITY OF FEEDS AS DETERMINED WITH STEERS AND AS DETERMINED WITH SHEEP

Species	No. of trials	Mean coefficients of digestibility in per cent						
		Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract	T.D.N. in dry matter
Timothy hay. Experiment 4. Nec. "t" at P = 0.05 is 2.306								
Steers	5	52.9	54.1	47.9	28.0	45.7	61.8	51.6
Sheep	5	49.0	50.1	39.1	30.1	42.0	58.1	49.7
	Diff.	+3.9	+4.0	+8.8	−2.1	+3.7	+3.7	+ 1.9
	"t"	2.483	2.779	1.893	2.455	1.351	2.580	2.694
Timothy hay. Experiment 3. Nec. "t" at P = 0.05 is 2.365								
Steers	4	54.6	55.9	45.4	18.2	55.6	58.8	53.1
Sheep	5	52.3	53.3	42.3	22.8	51.5	59.0	50.8
	Diff.	+2.3	+2.6	+3.1	−4.6	+4.1	−0.2	+ 2.3
	"t"	2.252	2.327	0.920	1.037	2.388	0.021	1.870
Alfalfa hay. Experiment 4. Nec. "t" at P = 0.05 is 2.306								
Steers	5	60.2	61.1	69.2	13.8	49.7	67.3	56.1
Sheep	5	59.6	60.0	69.5	12.0	47.3	66.7	55.2
	Diff.	+0.6	+1.1	−0.3	+1.8	+2.4	+0.6	+ 0.9
	"t"	0.908	1.545	0.169	0.849	1.342	0.859	1.308
Mixed clover and alfalfa hay. Experiment 2. Nec. "t" at P = 0.05 is 2.447								
Steers	4	53.2	54.7	55.8	47.1	43.9	63.6	51.55
Sheep	4	52.5	53.9	52.2	36.3	41.8	61.6	50.75
	Diff.	+0.7	+0.8	+3.6	+10.8	+2.1	+2.0	+ 0.80
	"t"	1.017	1.126	1.852	1.017	0.542	2.151	1.346
Corn silage. Experiment 3. Nec. "t" at P = 0.05 is 2.201								
Steers	6	61.3	63.6	41.9	61.4	62.6	67.3	61.8
Sheep	7	56.2	58.6	37.6	51.7	57.2	62.8	56.8
	Diff.	+5.1	+5.0	+4.3	+9.7	+5.4	+4.5	+ 5.0
	"t"	3.387	3.319	1.643	1.818	2.010	3.415	3.431
Corn silage from grain. Experiment 1. Nec. "t" at P = 0.05 is 2.02								
Steers	30	63.2	65.4	45.1	64.0	81.8	68.0	63.5
Sheep	11	50.2	53.5	23.8	53.5	60.3	58.4	50.6
	Diff.	+13.0	+11.9	+21.3	+10.5	+21.5	+9.6	+12.9
	"t"	8.219	7.805	*	5.52	3.134	7.190	8.189

* Variation too great in sheep for statistical analysis.

TABLE 1.—COMPARISON OF MEAN COEFFICIENTS OF DIGESTIBILITY OF FEEDS AS DETERMINED WITH STEERS AND AS DETERMINED WITH SHEEP—*Continued*

Species	No. of trials	Mean coefficients of digestibility in per cent						
		Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract	T.D.N. in dry matter
Barley-oat hulls 1 : 1. Experiment 3. Nec. "t" = 2.201								
Steers	4	67.4	69.5	75.5	63.1	30.3	75.3	69.6
Sheep	9	73.3	74.8	73.1	78.7	43.5	80.6	74.9
	Diff.	−5.9	−5.3	+2.4	−15.6	−13.2	−5.3	− 5.3
	"t"	2.526	2.402	0.879	2.916	2.683	1.525	2.441
Barley. Experiment 3. Nec. "t" = 2.201								
Steers	6	76.5	78.2	74.0	68.2	−0.7	85.9	78.2
Sheep	7	79.1	81.8	74.1	77.0	28.0	88.1	82.1
	Diff.	−2.6	−3.6	−0.1	−8.8	−28.7	−2.2	− 3.9
	"t"	1.613	2.301	0.058	1.132	1.466	1.048	2.837
Barley. Experiment 4. Nec. "t" at P of 0.05 is 2.228								
Steers	6	79.0	80.5	73.6	73.6	10.8	88.4	80.7
Sheep	6	81.4	82.7	76.8	80.8	34.0	88.6	82.6
	Diff.	−2.4	−2.2	−3.2	−7.2	−23.2	−0.2	− 1.9
	"t"	2.346	2.180	1.063	1.219	3.191	0.304	1.492
Grain mixture. Experiment 1. Nec. "t" at P of 0.05 is 2.306								
Steers	6	76.9	79.1	79.7	75.4	31.0	84.9	78.24
Sheep	4	76.8	78.6	78.8	84.6	42.6	82.9	78.37
	Diff.	+0.1	+0.5	+0.9	−9.2	−11.6	+2.0	− 0.13
	"t"	0.126	0.776	0.563	0.166	3.605	3.015	0.178
Timothy hay-barley. Experiment 4. Nec. "t" at P of 0.05 is 2.201								
Steers	7	62.4	64.1	64.3	57.2	43.7	73.3	62.5
Sheep	6	61.0	62.6	60.4	55.4	41.1	72.7	61.0
	Diff.	+1.4	+1.5	+3.9	+1.8	+2.6	+0.6	+ 1.5
	"t"	0.892	0.974	1.206	0.621	0.869	0.549	0.991
Timothy hay-barley. Experiment 3. Nec. "t" at P of 0.05 is 2.447								
Steers	4	62.6	64.2	59.6	36.0	50.8	69.8	62.3
Sheep	4	58.4	60.0	51.3	36.1	46.1	67.7	56.2
	Diff.	+4.2	+4.2	+8.3	−0.1	+4.7	+2.1	+ 6.1
	"t"	2.656	2.558	4.622	0.016	1.839	0.894	1.949

TABLE 1.—COMPARISON OF MEAN COEFFICIENTS OF DIGESTIBILITY OF FEEDS AS DETERMINED WITH STEERS AND AS DETERMINED WITH SHEEP—*Continued*

Species	No. of trials	Mean coefficients of digestibility in per cent						
		Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract	T.D.N. in dry matter
Oats calculated from hay. Experiment 2. Nec. "t" at P = 0.05 is 2.447								
Steers	4	66.1	67.4	71.3	85.6	14.5	75.3	69.03
Sheep	4	73.4	75.3	74.8	92.6	25.9	80.6	77.21
	Diff.	−7.3	−7.9	−3.5	−7.0	−11.4	−5.3	− 8.18
	"t"	2.448	2.821	0.967	2.551	—	2.915	2.841
Alfalfa hay-barley. Experiment 4. Nec. "t" at P of 0.05 = 2.306								
Steers	5	67.9	69.2	72.3	51.0	44.7	78.5	66.0
Sheep	5	67.5	68.8	71.0	49.5	45.9	78.0	65.7
	Diff.	+0.4	+0.4	+1.3	+1.5	−1.2	+0.5	+0.3
	"t"	0.370	0.400	0.778	0.549	0.531	0.630	0.280

live weights. The hay consisted of approximately 60 per cent clover (red and alsike), 30 per cent alfalfa, with the remainder timothy and a small amount of weeds. The oats were "Victory," grown at the Experimental Farm.

Experiment No. 3

Four grade Shorthorn steers and four Leicester-Shropshire crossed sheep were used. The rations fed were corn silage alone; timothy hay alone; barley alone; a mixed ration of barley and oat hulls in the ratio of 1 : 1, and a mixed ration of timothy hay with barley in the ratio of 2 : 1. Comparisons between the species were made on the basis of the coefficients of digestibility of timothy hay, corn silage, barley, and the two mixed rations. Again, as in the former experiment, the amounts fed to the sheep were based on the ratio of the 0.73 power of the live weights. The timothy hay was low grade. The barley was Western No. 1.

Experiment No. 4

Five grade Shorthorn steers and five Leicester-Shropshire crossed sheep were used. The rations consisted of timothy hay alone; alfalfa hay alone; barley alone; mixed rations of timothy hay with barley and alfalfa hay with barley in the ratio of 5 : 3. The timothy hay contained approximately 75 per cent timothy, 15 per cent legumes, and the remainder couch grass and weeds. The alfalfa was a second cut, good grade alfalfa. The barley was "Velvet" grown at the Experimental Farm. The comparison of the digestive powers of the two species was based upon the coefficients of digestibility of timothy fed alone; alfalfa fed alone; barley fed alone, and the mixed rations of timothy with barley and alfalfa with barley.

TABLE 2.—COMPOSITE COMPARISON OF DIGESTIBILITY OF FIVE RATIONS BY SHEEP AND STEERS

Nutrient	Species	Mean coefficients of digestibility in per cent of following feed†						Differences between means of coefficients of all feeds
		Barley‡	Timothy hay	Alfalfa hay	Barley calculated from mixed rations with Timothy*	Barley calculated from mixed rations with Alfalfa	Means	
Dry matter	Steers	79.0	52.9	60.2	78.7	80.6	70.9	
	Sheep	81.4	49.0	59.6	81.4	80.6	71.2	
	Diff.	− 2.4	+ 3.9	+ 0.6	− 2.7	0		− 0.3
Organic matter	Steers	80.5	54.1	61.1	80.8	81.8	72.3	
	Sheep	82.7	50.1	60.0	83.3	82.5	72.6	
	Diff.	− 2.2	+ 4.0	+ 1.1	− 2.5	− 0.7		− 0.3
Nitrogen	Steers	73.6	47.9	69.2	78.2	78.1	69.7	
	Sheep	76.8	39.1	69.5	79.0	73.8	68.1	
	Diff.	− 3.2	+ 8.8	− 0.3	− 0.8	+ 4.3		+ 1.6
Ether extract	Steers	73.6	28.0	13.8	84.4	85.5	58.7	
	Sheep	80.8	30.1	12.0	78.9	84.1	58.9	
	Diff.	− 7.2	− 2.1	+ 1.8	+ 5.5	+ 1.4		− 0.2
Crude fibre	Steers	10.8	45.7	49.7	10.2	6.3	23.5	
	Sheep	34.0	42.0	47.3	31.1	34.5	37.4	
	Diff.	−23.2	+ 3.7	+ 2.4	−20.9	−28.2		−13.9
N-free extract	Steers	88.4	61.8	67.3	85.9	89.0	79.1	
	Sheep	88.6	58.1	66.7	89.0	88.6	79.0	
	Diff.	− 0.2	+ 3.7	+ 0.6	− 3.1	+ 0.4		+ 0.1
T.D.N. in dry matter	Steers	80.7	51.6	56.1	81.5	82.1	70.8	
	Sheep	82.6	47.8	55.2	83.6	83.1	71.0	
	Diff.	− 1.9	+ 3.8	+ 0.9	− 2.1	− 1.0		− 0.2

* Omitting median value for sheep.
‡ Omitting median value for steers.
† Number of individual values averaged for each species:

Barley	6
Timothy hay	5
Alfalfa hay	5
Barley and timothy	6
Barley and alfalfa	5

RESULTS

The individual coefficients of digestibility in these experiments are given in Appendix Tables 3 to 18. A summary of the mean coefficients of digestibility of the different rations for each species is given in Text Table 1.

In the case of timothy hay, it will be seen in both Experiments 3 and 4, that the coefficients of digestibility with steers were slightly higher than the values with sheep for most of the nutrients. The differences were just statistically significant in Experiment 4 but not quite significant in Experiment 3. In both cases, while the T.D.N. tended to be higher with steers than with sheep, the differences were not statistically significant. For both

the alfalfa hay in Experiment 4 and the mixed clover and alfalfa hay in Experiment 2, the steers again tended to give higher coefficients of digetibility but the differences were not statistically significant. With corn silage in both Experiment 3 and Experiment 1 the steers definitely digested the silage better than the sheep. With the mixture of oat hulls and barley in Experiment 3, and the oats calculated from the ration with hay in Experiment 2, the coefficients for the sheep were higher than those for the steers. The differences were statistically significant. In the case of barley in Experiments 3 and 4, the coefficients of digestibility were higher with sheep than with steers. However, in most cases the differences were not statistically significant or else were just significant. The grain mixture of barley, wheat bran and oil cake meal fed in Experiment 1, was digested almost equally well by sheep as by steers. With the timothy hay-barley rations in Experiments 3 and 4, the coefficients for steers were higher than those for sheep. In the case of Experiment 4, none of the differences was statistically significant. In the case of Experiment 3, the differences for dry matter, organic matter and nitrogen were just significant but not significant for the total digestible nutrients. Finally, for the alfalfa hay-barley ration fed in Experiment 4, there were no differences between the two species in their powers of digestibility.

To present an over-all picture of the comparative digestive powers of sheep and steers for various rations, Table 2 has been constructed based on the results of Experiment 4.

In this table the mean coefficients of digestibility of barley alone, timothy alone, alfalfa alone, barley calculated from a mixed ration with timothy and barley calculated from a mixed ration with alfalfa, have been arranged by ration and by species. The data were subjected to an analysis of variance. The means for the five feeds for each species for each nutrient have been listed in the second-last column with their differences in the last column. These differences were not statistically significant.

SUMMARY AND CONCLUSIONS

Since 1939 experiments have been carried out to determine the comparative digestive powers of sheep and steers. The minimum number of animals used in any one trial was 4. The experiments were set up as randomized Latin squares. The rations used were dried roughages, succulent roughages, grain mixtures and single grains.

It was found that steers digested the corn silage better than sheep.

Steers tended to digest hays slightly better than sheep. The differences were not very great and in general not statistically significant.

Sheep tended to digest grain a little better than steers but the differences were not great and, with the exception of oats calculated from a mixed ration with hay, were not statistically significant.

With both oats and oat hulls sheep digested the ration better than steers.

When the results with rations of timothy hay, alfalfa hay, barley, timothy and barley, alfalfa and barley, were composited there was no difference between the digestive powers of the two species.

It was concluded that in these experiments there were some slight differences in the digestive powers of sheep and steers. With most feeds these were not of very great magnitude.

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APPENDIX

TABLE 3.—MEAN CHEMICAL COMPOSITION OF FEEDS USED IN EXPERIMENT 1

Feed	No. of values	Original composition		Mean chemical composition of dry matter				
		Moisture	Nitrogen	Ash	Protein*	Ether extract	Crude fibre	N-free extract
		%	%	%	%	%	%	%
Corn silage	6	77.49	0.287	5.63	7.77	1.84	28.32	56.46
Barley	6	15.14	—	2.81	12.76	1.02	6.08	77.34
Bran	6	13.70	—	5.93	17.99	4.42	12.11	59.55
Oil cake	6	7.36	—	6.70	33.27	6.60	7.68	45.75

* Protein factors:
[Jones (8)]

Silage	N × 6.25
Barley	N × 5.83
Bran	N × 6.31
Oil Cake	N × 5.30

APPENDIX—*Continued*

TABLE 4.—MEAN DAILY FOOD CONSUMPTION IN KILOGRAMS IN EXPERIMENT 1

Species	Consumption of basal grain ration fed alone and silage fed with this basal ration							
	Basal grain	Silage at following levels						
		I	II	III	IV	V	VI	VII
Steers	3.0	—	4.0	—	9.0	14.0	18.5	20.4
Sheep	0.6	0.5	0.8	1.22	—	—	—	—

TABLE 5.—INDIVIDUAL COEFFICIENTS OF DIGESTIBILITY OF FEEDS WITH SHEEP—EXPERIMENT 1

Nutrient	Animal No.	Coefficients of digestibility in per cent			
		Grain	Silage calculated from rations with grain		
			Level I	Level II	Level III
Dry matter	1	76.8	46.3	48.4	—
	2	77.9	39.2	52.4	50.9
	3	75.2	42.7	53.8	48.7
	4	77.4	53.1	57.5	58.7
Organic matter	1	78.9	50.5	52.7	—
	2	79.6	42.5	56.1	54.6
	3	77.2	47.2	56.8	51.8
	4	78.8	54.9	59.5	61.5
Nitrogen	1	75.6	−37.5	−16.0	—
	2	80.1	−31.3	28.0	20.0
	3	79.4	−56.3	36.0	31.8
	4	80.1	−37.5	24.0	36.6
Ether extract	1	85.2	68.8	64.9	—
	2	86.2	47.8	56.8	33.8
	3	82.8	78.6	68.6	60.3
	4	84.1	59.3	45.5	79.3
Crude fibre	1	44.3	58.6	51.3	—
	2	45.3	43.0	49.4	58.8
	3	40.8	45.9	53.3	44.1
	4	40.0	61.5	63.5	59.0
N.F.E.	1	83.4	54.7	60.8	—
	2	83.7	49.1	61.2	57.7
	3	81.3	57.3	60.2	56.2
	4	83.1	59.3	61.2	64.4
T.D.N.	1	78.31	47.34	50.26	—
	2	79.50	39.38	53.4	52.23
	3	77.17	44.11	54.80	39.26
	4	78.50	50.35	56.34	59.29

APPENDIX—*Continued*

TABLE 6.—INDIVIDUAL COEFFICIENTS OF DIGESTIBILITY OF FEEDS WITH STEERS—EXPERIMENT 1

Nutrient	Animal No.	Coefficients of digestibility in per cent					
		Grain	Silage calculated from ration with grain				
			Level II	Level IV	Level V	Level VI	Level VII
Dry matter	1	76.9	59.5	70.8	59.5	58.8	57.9
	2	76.0	65.3	68.9	62.3	63.7	59.4
	3	78.4	70.2	67.3	60.7	60.4	59.7
	4	78.4	65.9	68.1	70.9	60.8	65.8
	5	76.6	60.8	62.6	58.7	63.7	63.0
	6	75.3	61.5	62.3	64.8	60.9	59.4
Organic matter	1	79.9	62.5	73.4	62.0	60.9	59.9
	2	78.2	68.5	71.0	64.6	65.8	61.4
	3	80.1	72.7	69.7	62.8	62.6	61.9
	4	79.9	66.1	69.7	73.2	63.1	68.1
	5	78.5	63.6	64.8	60.8	67.4	65.1
	6	77.9	64.5	64.8	66.8	62.8	61.7
Nitrogen	1	76.6	23.5	52.0	34.5	36.9	37.3
	2	78.8	40.6	51.3	35.9	53.8	40.2
	3	82.0	68.0	54.0	43.6	45.2	42.6
	4	83.5	54.2	58.2	69.6	44.0	58.3
	5	79.9	35.6	41.6	34.7	49.1	48.0
	6	77.5	31.1	35.5	48.9	44.2	41.3
Ether extract	1	57.0	53.3	75.8	62.1	57.2	60.5
	2	70.9	72.4	73.2	67.7	63.6	60.4
	3	83.2	72.7	65.4	60.8	61.2	58.4
	4	87.4	68.1	67.3	70.3	64.0	62.6
	5	79.7	66.7	63.8	59.3	63.1	62.8
	6	74.2	60.8	66.2	60.9	60.1	60.6
Crude fibre	1	38.3	53.3	75.8	62.1	57.2	60.5
	2	25.6	72.4	73.2	67.7	63.6	60.4
	3	38.3	72.7	65.4	60.8	61.2	58.4
	4	25.6	68.1	67.3	70.3	64.0	62.6
	5	27.3	66.7	63.8	59.3	63.1	62.8
	6	31.1	60.8	66.2	60.9	60.1	60.6
N.F.E.	1	86.6	68.7	75.6	64.8	65.5	61.9
	2	84.3	71.6	72.1	65.7	68.5	64.6
	3	84.8	73.6	72.0	65.8	64.3	64.6
	4	85.4	65.8	71.6	74.7	64.7	71.7
	5	84.1	64.5	68.1	64.1	71.3	68.1
	6	84.0	68.8	66.8	71.1	65.5	64.6
T.D.N.	1	78.12	58.41	71.68	59.76	58.80	58.09
	2	76.92	64.62	68.76	62.34	64.13	59.31
	3	79.77	72.19	66.72	61.25	60.63	59.61
	4	79.66	65.11	67.88	71.28	61.15	65.98
	5	77.76	61.93	63.76	58.88	65.08	63.18
	6	77.19	64.62	62.76	64.52	60.76	59.86

APPENDIX—*Continued*

TABLE 7.—MEAN CHEMICAL COMPOSITION OF FEEDS USED IN EXPERIMENT 2

Feed	No. of values	Original moisture	Mean chemical composition of dry matter				
			Ash	Protein*	Ether extract	Crude fibre	N-free extract
		%	%	%	%	%	%
Hay	5	11.86	7.48	12.61	2.04	36.33	41.54
Oats	6	13.89	3.53	12.86	3.74	12.00	67.86

* Protein factor: [Jones (8)] N × 6.25 for hay; N × 5.83 for oats.

TABLE 8.—MEAN DAILY FOOD CONSUMPTION IN KILOGRAMS IN EXPERIMENT 2

Species	Hay fed alone	Hay + Oats	
		Hay	Oats
Steers	6.25	5.0	3.0
Sheep	0.50	0.5	0.3

TABLE 9.—INDIVIDUAL COEFFICIENTS OF FEEDS WITH SHEEP—EXPERIMENT 2

Feed	Animal No.	Coefficients of digestibility of nutrients in per cent						
		Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract	T.D.N. in dry matter
Hay	1	53.0	54.1	51.4	15.4	47.3	60.5	50.53
	2	52.7	54.3	54.0	57.3	37.8	62.7	51.49
	3	51.1	52.5	55.6	59.1	33.2	62.0	50.14
	4	53.2	54.5	47.7	13.5	48.8	61.1	50.83
Oats from mixed ration	1	73.0	74.6	74.0	94.4	29.8	80.5	77.55
	2	74.5	76.6	78.2	88.4	29.9	80.8	77.84
	3	73.3	75.0	78.2	91.7	14.6	80.5	76.49
	4	72.9	75.0	68.8	96.0	29.2	80.6	76.95

APPENDIX—*Continued*

TABLE 10.—INDIVIDUAL COEFFICIENTS OF FEEDS WITH STEERS—EXPERIMENT 2

Feed	Animal No.	Coefficients of digestibility of nutrients in per cent						
		Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract	T.D.N. in dry matter
Hay	1	54.6	56.1	55.3	47.4	45.7	65.6	53.00
	2	52.4	53.6	53.5	48.4	41.5	64.0	50.65
	3	52.9	54.8	57.5	40.0	45.1	62.9	51.60
	4	52.7	54.1	56.9	52.5	43.1	61.9	50.96
Oats from mixed ration	1	67.0	68.3	73.7	85.3	11.8	77.3	70.43
	2	72.2	73.9	80.1	76.1	15.7	81.2	73.57
	3	68.6	70.1	74.4	83.3	23.9	77.5	71.94
	4	71.6	73.0	73.6	85.6	10.4	82.1	73.49

TABLE 11.—CHEMICAL COMPOSITION OF FEEDS USED IN EXPERIMENT 3

Feed	No. values	Original composition		Chemical composition of dry matter				
		Moisture	Nitrogen	Ash	Protein*	Ether extract	Crude fibre	N-free extract
		%	%	%	%	%	%	%
Corn silage	2	21.78	0.274	5.22	7.22	1.44	30.99	55.14
Hay	5	88.60	1.019	5.58	7.18	2.15	34.25	50.86
Barley	8	86.64	1.869	2.90	12.57	1.96	7.04	75.54

* Corn silage and hay N × 6.25.
Barley N × 5.83.
[Jones (8)]

TABLE 12.—MEAN DAILY FOOD CONSUMPTION IN KILOGRAMS IN EXPERIMENT 3

Species	Kilograms per animal per day				
	Hay	Hay-barley ration: Hay	Hay-barley ration: Barley*	Barley alone	Silage
Steers	7.0	4.0	2.0	2.6	14.0
Sheep	1.3	0.8	0.4	0.41	2.2

* Slight adjustments were made in the weight of the barley fed for each digestion trial in order to maintain a constant ratio of the dried weights of the two feeds.

APPENDIX—*Continued*

TABLE 13.—INDIVIDUAL COEFFICIENTS OF DIGESTIBILITY IN EXPERIMENT 3

Feed	Species	Coefficients of digestibility in per cent						
		Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract	T.D.N. in dry matter
Corn silage	Sheep	57.8	60.0	40.2	65.3	58.2	64.0	57.5
		56.2	58.7	35.1	67.1	56.9	63.2	57.3
		61.9	64.7	45.7	60.2	64.5	68.0	62.9
		54.4	56.6	33.3	40.3	54.8	61.2	54.7
		53.6	55.8	30.1	37.7	55.1	60.4	54.0
		56.4	58.6	39.7	41.6	57.5	62.3	56.6
		53.2	55.9	38.3	50.0	53.4	60.3	54.4
	Steers	64.2	65.9	49.7	67.1	63.9	69.6	64.2
		58.7	60.9	40.1	64.4	58.0	65.5	59.3
		63.1	65.4	42.0	63.7	64.5	69.5	63.3
		62.5	65.2	43.2	57.2	66.3	67.6	63.1
		59.8	62.4	39.1	58.1	60.9	66.4	60.5
		59.2	62.0	37.1	58.1	62.1	65.3	60.1
Hay	Sheep	54.4	55.9	44.9	27.3	55.9	58.8	53.7
		50.9	51.9	41.8	23.1	50.3	55.0	49.2
		51.3	52.2	50.7	12.7	49.6	56.1	49.8
		51.5	52.4	33.6	19.6	49.9	57.1	49.7
		53.2	54.0	40.5	31.4	51.9	57.9	51.7
	Steers	56.4	57.9	47.1	25.7	58.1	60.6	55.5
		52.6	53.9	46.9	19.5	52.3	57.4	51.2
		54.9	56.1	46.0	12.7	56.8	58.2	53.0
		54.3	55.5	41.6	14.8	55.2	58.8	52.7
Hay-barley 2 : 1	Sheep	55.0	56.5	52.4	43.2	41.7	63.9	47.2
		61.8	63.7	52.5	26.7	51.4	71.0	61.2
		58.4	59.6	48.5	33.7	44.2	68.3	57.8
		58.7	60.0	51.6	40.8	47.1	67.6	58.4
	Steers	60.4	62.1	62.1	48.2	49.5	67.9	60.5
		63.7	65.3	56.8	26.0	52.3	72.9	62.8
		63.3	64.9	57.0	29.1	50.7	72.9	62.7
		63.0	64.6	62.3	40.5	—	65.6	63.0
Barley alone	Sheep	79.9	81.7	70.6	77.6	20.7	88.4	81.8
		79.3	80.9	71.9	87.4	40.4	87.0	82.1
		82.1	84.2	73.6	64.1	43.3	89.7	83.7
		73.9	—	77.6	—	—	—	—
		79.1	—	71.9	—	—	—	—
		82.7	83.8	81.0	74.3	23.4	90.0	84.0
		76.4	78.3	72.4	81.7	12.0	85.4	78.7
	Steers	80.0	81.9	71.2	37.2	23.5	89.0	80.9
		74.3	76.0	74.8	78.3	63.6	84.8	77.1
		76.2	77.9	72.8	71.0	−37.5	88.6	77.6
		75.1	71.1	73.2	74.6	—	77.8	77.5
		73.7	75.2	75.3	74.5	−56.9	86.2	75.0
		79.4	81.1	76.7	73.4	3.9	89.0	81.2

APPENDIX—*Continued*

TABLE 14.—MEAN CHEMICAL COMPOSITION OF FEEDS IN EXPERIMENT 4

Feed	No. of values	Original moisture	Chemical composition of dry matter				
			Ash	Protein[1]	Ether extract	Crude fibre	N-free extract
Alfalfa	5	15.40	8.11	16.69	1.19	31.76	42.25
Timothy	5	13.14	5.23	7.16	1.10	37.79	48.72
Barley	5	14.36	3.14	13.90	2.12	6.74	74.11

[1] Protein factors, timothy and alfalfa N × 6.25 [Jones (8)]
barley N × 5.83

TABLE 15.—MEAN DAILY FOOD CONSUMPTION IN KILOGRAMS IN EXPERIMENT 4

Species	Daily consumption of following ration						
	Alfalfa Hay	Timothy Hay	Barley	Alfalfa-barley ration		Timothy-barley ration	
				Alfalfa	Barley	Timothy	Barley
Steers	6.1	6.0	2.5	4.4	2.6	4.2	2.5
Sheep	0.70	0.59	0.39	0.46	0.27	0.41	0.25

TABLE 16.—INDIVIDUAL COEFFICIENTS OF DIGESTIBILITY IN EXPERIMENT 4

Feed	Species	Coefficients of digestibility in per cent						
		Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract	T.D.N. in dry matter
Timothy	Sheep	50.7	51.5	37.8	38.9	39.5	61.5	48.9
		45.1	46.7	33.9	21.2	37.0	56.3	44.3
		51.3	52.4	41.8	16.7	47.3	58.9	50.2
		45.8	47.3	28.8	30.6	43.0	53.9	45.3
		51.9	52.7	53.2	43.1	43.4	59.7	50.4
	Steers	50.7	51.7	46.3	37.9	37.9	62.3	49.3
		53.2	54.8	44.7	13.5	47.7	63.1	52.3
		52.7	54.2	46.1	9.0	46.3	62.4	51.6
		54.3	55.4	46.2	38.3	50.4	61.0	52.9
		53.5	54.4	56.4	41.5	46.4	60.2	51.9
Alfalfa	Sheep	58.8	59.3	65.0	12.0	45.9	68.1	54.6
		59.2	59.7	69.8	9.2	48.2	65.8	55.0
		60.2	60.4	71.4	10.3	48.4	66.2	55.4
		58.6	59.3	68.0	18.6	47.9	65.5	54.8
		61.0	61.2	73.3	10.1	46.1	67.9	56.1
	Steers	59.2	60.0	65.1	17.7	49.4	67.0	55.4
		61.4	62.3	70.9	14.0	52.0	68.3	57.6
		59.7	59.9	70.0	9.7	47.3	65.9	54.7
		61.4	62.8	69.1	13.7	54.7	67.3	57.7
		59.5	60.4	70.7	13.9	45.0	68.2	55.2

APPENDIX—*Continued*

TABLE 16.—INDIVIDUAL COEFFICIENTS OF DIGESTIBILITY IN EXPERIMENT 4—*Continued*

Feed	Species	Coefficients of digestibility in per cent						
		Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract	T.D.N. in dry matter
Barley	Sheep	82.8	84.4	79.4	81.9	37.8	90.0	84.6
		79.3	81.0	75.0	82.8	30.5	86.9	81.6
		82.4	83.4	72.4	86.4	40.0	89.0	83.7
		79.8	80.8	75.2	84.3	28.0	87.3	80.9
		84.2	85.7	81.8	72.2	46.6	90.6	85.3
		79.9	81.0	77.9	77.1	20.9	87.5	80.7
	Steers	80.1	82.1	71.5	64.6	35.4	88.7	81.6
		78.9	80.1	—	78.4	9.3	87.5	77.8
		76.6	78.6	65.1	50.5	0.6	88.3	80.6
		78.5	80.3	74.3	83.5	−3.9	88.8	80.8
		78.6	80.1	78.4	79.1	1.2	88.3	82.8
		81.0	82.0	78.5	85.6	22.5	88.5	—
Timothy-barley	Sheep	59.7	61.5	61.8	53.3	34.5	73.3	60.0
		61.6	63.0	61.1	55.1	42.2	73.1	61.6
		56.2	58.1	45.5	60.9	34.3	70.5	56.3
		63.0	64.1	63.3	62.0	45.2	73.2	62.8
		61.2	62.8	65.9	54.3	42.6	71.7	61.4
		64.3	66.0	65.0	46.7	47.8	74.6	64.0
	Steers	62.5	63.7	65.2	60.6	38.7	74.0	62.0
		65.8	67.4	69.9	61.9	47.0	76.6	65.9
		61.0	62.7	60.8	52.1	42.4	72.5	61.0
		58.9	60.3	62.2	62.2	37.1	70.7	59.1
		63.8	65.5	66.2	58.4	45.5	74.3	63.8
		59.4	61.3	59.0	54.9	42.5	70.1	59.9
		65.7	67.5	66.9	50.0	52.5	74.8	65.9
Alfalfa-barley	Sheep	66.0	67.8	67.7	43.6	45.0	77.5	64.5
		68.4	69.4	74.4	46.5	46.5	78.9	66.5
		65.6	66.8	67.9	45.6	43.0	76.5	63.5
		67.4	68.6	70.4	55.6	47.2	77.3	65.8
		70.2	71.2	74.4	56.2	47.7	79.7	68.0
	Steers	69.3	70.7	72.9	52.3	48.7	79.4	67.4
		69.1	70.3	73.6	52.0	47.0	79.9	67.3
		66.0	67.4	69.3	48.8	43.0	76.8	63.9
		68.6	69.6	73.1	51.5	47.4	78.2	66.7
		66.5	67.8	72.8	50.4	37.2	78.1	64.5

APPENDIX—*Continued*

TABLE 17.—COMPARISON OF COEFFICIENTS OF DIGESTIBILITY OF SHEEP AND STEERS, USING COEFFICIENTS OF DIGESTIBILITY OF INDIVIDUAL FEEDS IN EXPERIMENT 4

Nutrient	Species	Coefficient of digestibility					Means for species
		Barley	Timothy	Alfalfa	Barley calculated from Timothy*	Barley calculated from Alfalfa	
Dry matter	Steer	80.1	50.7	59.2	—	84.5	
		78.9	53.2	61.4	87.8	84.1	
		76.6	52.7	59.7	74.8	75.4	
		78.5	54.3	61.4	69.0	82.0	
		78.6	53.5	59.5	82.6	76.9	
		81.0	—	—	70.6	—	
		—	—	—	87.5	—	
	Means	79.0	52.9	60.2	78.7	80.6	70.9
	Sheep	82.8	50.7	58.8	77.8	76.5	
		79.3	45.1	59.2	83.0	83.3	
		82.4	51.3	60.2	68.4	75.4	
		79.8	45.8	58.6	86.5	79.8	
		84.2	51.9	61.0	82.1	87.9	
		79.9	—	—	90.8	—	
	Means	81.4	49.0	59.6	81.4	80.6	71.2
Total	Means	80.2	50.9	59.9	80.1	80.6	
Organic matter	Steer	82.1	51.7	60.0	89.6	86.0	
		80.1	54.8	62.3	77.1	85.1	
		78.6	54.2	59.9	70.3	77.1	
		80.3	55.4	62.8	84.7	82.6	
		80.1	54.4	60.4	73.4	78.2	
		82.0	—	—	89.8	—	
	Means	80.5	54.1	61.1	80.8	81.8	72.3
	Sheep	84.4	51.5	59.3	80.4	80.1	
		81.0	46.7	59.7	84.3	84.6	
		83.4	52.4	60.4	71.4	77.5	
		80.8	47.3	59.3	86.9	81.7	
		85.7	52.7	61.2	84.1	88.7	
		81.0	—	—	92.8	—	
	Means	82.7	50.1	60.0	83.3	82.5	72.6
Total	Means	81.6	52.1	60.5	82.1	82.2	
Nitrogen	Steer	71.5	46.3	65.1	87.5	79.5	
		65.1	44.7	70.9	70.9	81.6	
		74.3	46.1	70.0	72.8	69.5	
		78.4	46.2	69.1	83.2	79.8	
		78.5	56.4	70.7	69.6	80.1	
		—	—	—	85.3	—	
	Means	73.6	47.9	69.2	78.2	78.1	69.7
	Sheep	‡ 79.4	37.8	65.0	80.4	64.3	
		75.0	33.9	69.8	77.8	83.6	
		72.4	41.8	71.4	51.2	64.4	
		75.2	28.8	68.0	81.2	72.1	
		81.8	53.2	73.3	91.0	84.5	
		—	—	—	92.6	—	
	Means	76.8	39.1	69.5	79.0	73.8	68.1
Total	Means	75.2	43.5	69.3	78.6	75.9	

* Omitting median value for steer.
‡ Omitting median value for sheep.

APPENDIX—*Continued*

TABLE 17.—COMPARISON OF COEFFICIENTS OF DIGESTIBILITY OF SHEEP AND STEERS, USING COEFFICIENTS OF DIGESTIBILITY OF INDIVIDUAL FEEDS IN EXPERIMENT 4—*Continued*

Nutrient	Species	Coefficient of digestibility					Means for species
		Barley	Timothy	Alfalfa	Barley calculated from		
					Timothy*	Alfalfa	
Ether extract	Steer	64.6 78.4 50.5 83.5 79.1 85.6	37.9 13.5 9.0 38.3 41.5 —	17.7 14.0 9.7 13.7 13.9 —	90.9 88.8 68.3 94.6 89.8 74.2	89.9 85.5 80.7 87.5 84.0 —	
	Means	73.6	28.0	13.8	84.4	85.5	58.7
	Sheep	81.9 82.8 86.4 84.3 72.2 77.1	38.9 21.2 16.7 30.6 43.1 —	12.0 9.2 10.3 18.6 10.1 —	75.0 74.5 81.6 91.9 79.0 71.4	72.9 75.9 76.6 98.2 97.0 —	
	Means	80.8	30.1	12.0	78.9	84.1	58.9
Total	Means	77.2	29.1	12.9	81.7	84.8	
Crude fibre	Steer	35.4 9.3 0.6 −3.9 1.2 22.5	37.9 47.7 46.3 50.4 46.4 —	49.4 52.0 47.3 54.7 45.0 —	−25.0 59.3 8.5 −40.6 43.8 14.9	40.5 24.4 −11.8 30.8 −52.5 —	
	Means	10.8	45.7	49.7	10.2	6.3	23.5
	Sheep	37.8 30.5 40.0 28.0 46.6 20.9	39.5 37.0 47.3 43.0 43.4 —	45.9 48.2 48.4 47.9 46.1 —	−33.3 44.1 −45.8 73.6 48.1 100.0	26.7 39.8 8.5 46.6 51.0 —	
	Means	34.0	42.0	47.3	31.1	34.5	37.4
Total	Means	22.4	43.9	48.5	20.6	20.4	
N.F.E.	Steer	88.7 87.5 88.3 88.8 88.3 88.5	62.3 63.1 62.4 61.0 60.2 —	67.0 68.3 65.9 67.3 68.2 —	93.1 84.3 80.4 88.4 79.5 89.5	91.2 92.0 85.4 88.2 88.4 —	
	Means	88.4	61.8	67.3	85.9	89.0	79.1
	Sheep	90.0 86.9 89.0 87.3 90.6 87.5	61.5 56.3 58.9 53.9 59.7 —	68.1 65.8 66.2 65.5 67.9 —	90.7 89.9 84.0 89.6 86.9 93.1	87.9 90.5 85.5 87.0 92.1 —	
	Means	88.6	58.1	66.7	89.0	88.6	79.0
Total	Means	88.4	59.9	67.0	87.5	88.8	

* Omitting median value for steer.

APPENDIX—*Continued*

TABLE 17.—COMPARISON OF COEFFICIENTS OF DIGESTIBILITY OF SHEEP AND STEERS, USING COEFFICIENTS OF DIGESTIBILITY OF INDIVIDUAL FEEDS IN EXPERIMENT 4—*Continued*

Nutrient	Species	Coefficient of digestibility					Means for species
		Barley‡	Timothy	Alfalfa	Barley calculated from		
					Timothy*	Alfalfa	
T.D.N. in dry matter	Steer	81.6	49.3	55.4	90.3	86.1	
		77.8	52.3	57.6	77.0	86.1	
		80.6	51.6	54.7	72.0	76.9	
		80.8	52.9	57.7	85.3	83.7	
		82.8	51.9	55.2	74.2	77.7	
		—	—	—	90.4	—	
	Means	80.7	51.6	56.1	81.5	82.1	70.8
	Sheep	84.6	48.9	54.6	80.3	79.9	
		81.6	44.3	55.0	84.9	85.8	
		—	50.2	55.4	70.9	77.4	
		80.9	45.3	54.8	88.1	83.1	
		85.3	50.4	56.1	85.1	89.1	
		80.7	—	—	92.5	—	
	Means	82.6	47.8	55.2	83.6	83.1	71.0
Total	Means	81.7	49.7	55.6	82.6	82.6	

* Omitting median value for steer.
‡ Omitting median value for sheep.

TABLE 18.—ANALYSIS OF VARIANCE OF DATA IN TABLE 17

Nutrient	Variance due to	Variance	F
Dry matter	Ration	2,045.0491	*
	Species	1.1852	†
	Interaction	19.6338	†
	Error	20.7817	
Organic matter	Ration	2,155.1980	*
	Species	0.7350	†
	Interaction	19.0595	—
	Error	18.8321	1.012
Nitrogen	Ration	2,116.4230	*
	Species	35.8893	†
	Interaction	58.5051	†
	Error	61.7109	—
Ether extract	Ration	11,749.0503	*
	Species	0.3424	†
	Interaction	67.2118	†
	Error	92.8949	—
Crude fibre	Ration	2,000.8003	2.643
	Species	2,608.3350	3.445
	Interaction	588.9348	—
	Error	757.1064	—
N-free extract	Ration	1,991.9713	*
	Species	0.3112	†
	Interaction	16.4348	2.283
	Error	7.1986	—
T.D.N.	Ration	2,744.6726	*
	Species	0.2094	†
	Interaction	15.3824	†
	Error	20.4566	—

Nec. F at P of 0.05 $N_1 = 4, N_2 = 44$ is 2.59 at P of 0.01 = 3.78
Nec. F at P of 0.05 $N_1 = 4, N_2 = 42$ is 2.60 at P of 0.01 = 3.81
Nec. F at P of 0.05 $N_1 = 1, N_2 = 44$ is 4.06 at P of 0.01 = 7.25
Nec. F at P of 0.05 $N_1 = 1, N_2 = 42$ is 4.07 at P of 0.01 = 7.28

* Obviously significant.
† Obviously not significant.

A NOTE ON THE USE OF OIL AS A CARRIER FOR SMUT FUNGICIDES[1]

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Exploratory experiments on the use of oil as a carrier for smut fungicides were conducted in 1947. The results were promising, and it was thought that the information might be of interest to others investigating seed treatments.

The main objection to the use of dust fungicides is the general nuisance of free-flying dust particles encountered when treating seed or handling treated seed. Unless the dusting machine is equipped with a device for removing excess dust, the operator, except when working with a mask or under ideal conditions, finds most dusts irritating, and occasionally illness results. The objectionable features of dust treatments have been somewhat overcome by the introduction of the slurry type of treater in which the fungicide is applied in the form of a water suspension.

It occurred to the writer, however, that it might be possible to dissolve or suspend the fungicide in oil to eliminate the dust nuisance. After some preliminary trials with various oils, a light white mineral oil such as is used for medicinal purposes was selected for further tests. Various fungicides were tested but the mercury dusts Ceresan and Leytosan appeared most satisfactory. It was necessary to use the gross dust in these tests whereas the possibilities of mixtures of the pure fungicide in oil might also be considered for future work.

Tests to determine coverage were made, and it was found that about 1 cc. of the mineral oil would cover 1 pound of wheat seed, or roughly 60 cc. per bushel. On this basis, the proportional amount of Ceresan, at the rate of ½ oz. per bushel, was mixed in 10 cc. of oil and 1 cc. aliquots of this were used in treating 1-pound lots of seed. In some cases, the rate was doubled, as 1 oz. of dust to 60 cc. of oil. Coverage was determined by plating the seed against a *Helminthosporium sativum* colony. Coverage was reasonably good with very little mixing. The treated grain did not have any objectionable oily nature. It had good flowability.

The toxicity of the oil and oil mixtures was determined by germination tests. Wheat seed treated with a Ceresan and oil mixture gave a germination of 91 per cent on blotters; and emergence in unsterilized soil gave results as follows: check, 64 per cent; oil only, 58 per cent; and oil and Ceresan, 88 per cent.

Field tests were laid out at Saskatoon and Indian Head, seeding being done at the former location on May 16 and at the latter on May 20. Red Bobs wheat and Victory oats were used in these tests. The former was inoculated with smut collected in Saskatchewan and probably was a mixture of *Tilletia caries* and *T. foetida*. The inoculum for the oat plots consisted largely of covered smut, *Ustilago Kolleri*. The inoculations were moderate to heavy. The plots were of 6 drills approximately 60 feet long.

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The crop at Saskatoon grew under warm dry conditions in general and at Indian Head under cool (early in the season) moist conditions. The emergence in all plots was good.

TABLE 1.—RESULTS OF FIELD EXPERIMENTS WITH MERCURY DUST CARRIED IN OIL FOR THE CONTROL OF SMUTS OF WHEAT AND OATS

Cereal	Treatment	Smut	
		Saskatoon	Indian Head
		%	%
Wheat	Check	58	3
	Oil+Leytosan at 1 oz. per bu.	0	0
	Oil+Leytosan at ½ oz. per bu.	Trace	Trace
	Oil+Ceresan at ½ oz. per bu.	1	Trace
Oats	Check	15	5
	Oil+Leytosan at 1 oz. per bu.	Trace	1

It will be seen that the oil treatments gave good control, indicating the possibilities of further investigations along this approach. If such treatments are feasible, it is quite likely the fungicide could be distributed for sale in oil as readily as in a dust carrier. The ease with which the oil spread over the seed, with gentle manipulation, indicates little difficulty in devising suitable application methods. Damage from frost would appear to be less with oil mixtures than with water mixtures.

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